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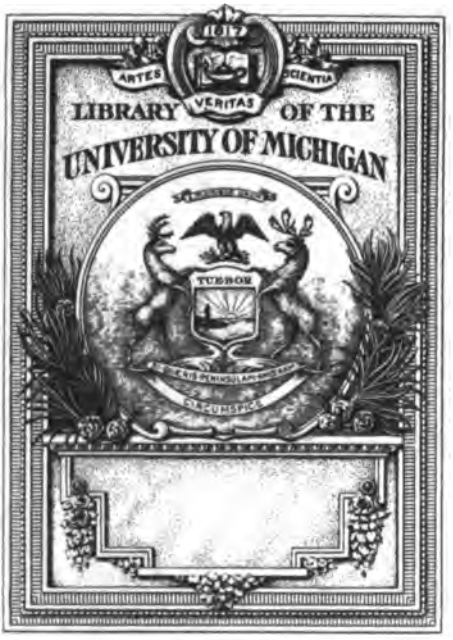

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UNIVERSITY STUDIES

VOL. XVI *JANUARY–APRIL 1916* NOS. 1, 2

I.—ECOLOGICAL INVESTIGATIONS UPON THE GERMINATION AND EARLY GROWTH OF FOREST TREES

BY RICHARD H. BOERKER

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PREFATORY NOTE

Almost every national industry makes provision for investigative work. Millions of dollars are spent annually to develop both human and mechanical efficiency. It is immaterial whether the investigations are for the purpose of utilizing certain products hitherto considered waste, or to make workmen more efficient, or to employ the latest processes and inventions to better survive in the competitive struggle—the results of this class of work are

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considered a great, indispensable business asset, warranting wholesome moral and financial support.

The history of our country reveals the fact that material industrial progress is largely in direct proportion to scientific research and invention. This is especially true in the agricultural pursuits. The various governmental bureaus, our state universities and agricultural colleges, and our many agricultural experiment stations are intimately connected with and responsible for the progressive agricultural development of our country. These institutions form a vast ganglionic intellectual organization; they are rapidly becoming the centers of a new agricultural system and, working from these centers outward, they are gradually touching every phase of agricultural activity.

Forestry has joined the ranks of the great industries in developing the investigative side of the business and the establishment of forest experiment stations and a forest products laboratory by the Forest Service of the United States Department of Agriculture has been the first step in this direction. It has become the business of these stations and this laboratory to study the fundamental laws governing the life of the forest and their effect upon the final product—wood. That vast complex of environmental factors—the habitat—is beginning to be analyzed to discover in what ways man can help nature to produce more and better timber, in a shorter length of time and at less cost than nature has produced in the ages past. While perhaps, on account of economic conditions, industrial investigations have been given preference to purely silvicultural research, yet investigations in establishing and growing forests have received no small amount of attention.

Outside of these governmental endeavors very little has been done along the lines of silvicultural research. State forest experiment stations are practically unknown. It is true that the foresters as well as the ecologists connected with some of our agricultural experiment stations are contributing to this field, but a beginning has scarcely been made. There is a great need for state forest experiment stations or at least for foresters upon the staffs of some of the agricultural experiment stations to help

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solve local forestry problems. Finally, there is no reason why forest experiment stations established and maintained by private endowment on the plan of the Desert Botanical Laboratory of the Carnegie Institution would not be able to do a great service along these lines.

The importance and need of silvicultural investigations scarcely needs comment, yet it might be well at the outset to emphasize certain fundamental concepts. Forests are one of our greatest natural resources. Unlike coal, iron, oil, etc., they can be *grown* to insure a continuous supply. *Forests are not huge warehouses of standing logs from which we can take our annual supply ad infinitum; they are not merely aggregations of individual trees; they are complex communities of living organisms capable of response to environmental factors not unlike human beings.* It follows then that in order to replace what we take from the forest, in other words, in order to *grow a neverfailing supply of timber intelligently and economically, we must understand these complex living organisms and communities, must study their behavior and requirements and ascertain the conditions under which they grow best.* This domain is forest ecology or silvics.

It has been asked, Does forestry in its present stage of development need this kind of work? Is not this work ahead of the times? Is it not of too little practical value to demand our attention at present? It will be my purpose to show at this point of my paper that, while this class of work is not absolutely essential to forestry at the present time, it is *extremely desirable* that it be begun in a *scientific* manner at the earliest possible moment, in order to put American forestry upon a firm scientific basis. The present status of forestry in the United States emphasizes the necessity of beginning soon. A brief word as to our present stage of development may be in order.

Forestry either of an intensive or an extensive nature is being practised in many parts of the country to-day. Both private and public corporations are engaged in one or more of the main phases of it, viz.: silviculture, forest protection, forest administration, or forest utilization. In the field of forest protection gigantic

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strides have been made in the last ten years on both public and private holdings, and obviously this is the first step towards forest management. Such intensive silvicultural operations as planting and thinning are being practised principally in the east, while extensive forestry involving the selection and shelterwood systems of management is almost the rule in the west. As might be expected, in the west forest planting is still in its experimental stage. On the whole economic conditions in the east have favored the development of both public and private forestry and hence this activity has been on a more intensive scale there than in the west. That forestry in some sections of the country is not developing as fast as some conservationists might wish is due to the fact that it is being held back by certain conditions and elements of environment which by their very nature belong to a new country with enormous natural resources like ours and over which human endeavor has no control. It must be realized that forestry never developed in any country in the world as fast as it has in the United States in the last twenty-five years, and that at the present time it is proceeding as fast as is consistent with sound principles and existing economic conditions.

While the practice of forestry is making rapid strides, silvicultural investigations are still in the infancy of their development. In other words the practice of forestry and the science of forestry have not developed in a ratio which would make them mutually helpful. The greater development of the applied phases of forestry is due partly to economic conditions and partly also to a lack of appreciation of the value of purely scientific research. The tendency has always been to magnify the industrial branch of a science at the expense of the main body from which it had its origin. Purely scientific botany has been largely lost sight of in the face of such of its branches as bacteriology, plant breeding, pathology, etc. Similarly the science of silvics has had to give way to seemingly more important phases concerned with the utilization of forests. In these days of commercial ideals when the value of most things is gauged by what they will bring on the market, I fear that undue emphasis has been placed upon the economic or applied phases of a science. Hence it is not strange

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that we should measure the value of purely scientific work in dollars and cents rather than in terms of scientific advance and intellectual satisfaction. The test nowadays applied to any science by the large majority of people is, How much money does it influence? What industries has it created? What has it added to the wealth of the world?

If purely investigative work in forestry must give a *raison d'être,* it might be well to call to mind the following facts: that many of its problems strike the foundations of national prosperity and their value cannot be measured in dollars and cents; that some of its problems must be gauged by the future returns they bring rather than by the present; and that it is the avowed purpose of scientific work to solve those problems in which the so-called practical worker has failed to produce results. History bears witness to the fact that those fields which have seemed furthest removed from utility have often yielded the most fruitful results. What seems of only scientific value to-day very often turns out to be of great practical utility later. It is comparatively easy to estimate the value of a piece of work when it is possible to base that estimate upon what has been actually gained; but how hopeless is very often the task when we must base our estimate upon the loss which it prevented. In such silvical investigations as the influence of forests upon stream flow, upon the water supply of communities, and upon the health and prosperity of our people *money values fade into insignificance.*

Silvicultural investigations as well as forestry business are long time propositions. The value of such work is very often measured not so much by the immediate financial returns it brings as by the principles it helps to establish, which in turn may affect our management and hence the financial returns many years hence. It is the *time* element more than any other that emphasizes the need for beginning the solution of some of our silvicultural problems soon. It is believed by many that it will be at least twenty-five years before intensive operations such as planting, thinning, and other silvicultural measures will be economically possible in some parts of the country. Granted that this is true. Is this too much time to devote in preparation for this work? If

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we keep on getting results in the next twenty-five years in the same proportion as we have done in the past ten, will many of our important problems be solved? Most silvicultural investigative problems take many years to solve. Some nursery and planting problems can be solved in from three to five years (if nothing interferes), but most of even these take longer. In many cases it takes from two to four years merely to raise stock let alone experiment with it. It usually takes six months or more to determine whether the stock set out will live, let alone establish principles in planting. The element of time is the largest factor in this work; we will need much of it, for failures will be numerous and this will mean the loss of many years. Only long time and carefully planned investigations can lead to stable and economic forest management.

With the development of forestry it cannot be doubted that a great deal of exact silvical and silvicultural knowledge is necessary, and we must admit that a great deal of data is needed to-day which cannot be furnished. We have unsystematic and indefinite knowledge about many phenomena which await experimental proof. In fact, forestry is loaded down with a vast weight of *undigested* facts, and pure science has only begun to relieve forestry of this burden. The quickest and surest way for purely forestry research to gain recognition is to show how to attain practical results which years of blind groping along applied lines have failed to accomplish.

Our task is a gigantic one, greater than any investigative problems that have confronted or will confront European nations. We have more species of trees important in forestry than all European nations combined. Our varied topographic and climatic conditions make our problems infinitely more complex and numerous. But that should not discourage us. Big problems concerning the forest have been solved in the past and are being attacked to-day. We have worked out our problems in logging and have developed machinery and methods unique in the history of forest industry; we have developed a system of forest fire protection unlike anything ever attempted by forestry-practicing nations; it remains for American ingenuity and enterprise to solve the silvicultural problems which confront the American forester.

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Briefly stated the purpose of the present investigation is to inquire into the effect of the more important habitat and seed factors upon the germination and early development of certain American forest trees in control cultures in the greenhouse for the purpose of obtaining data that may be used in the silvicultural management of these species.

This investigation has been conducted under the direction of Professor Raymond J. Pool and I am indebted to him for his friendly advice and counsel. I am especially grateful to him for having read the first draft of this paper and for offering valuable criticisms and suggestions. I wish to further acknowledge my indebtedness to Professors P. B. Barker and H. J. Young of the department of agronomy of the College of Agriculture for the mechanical analyses of the soils used in these experiments and to various members of the departments of botany and geology for the many courtesies extended to me. Thanks are due to the various district foresters, forest supervisors, and rangers, also members of the Washington office of the Forest Service for their kindness in furnishing so much of the seed used in these investigations. Without this material assistance a large part of this work would have been impossible. Grateful acknowledgment is also due to my wife for much valuable assistance in counting seeds, in compiling the final data and in reading proof. Also, I cannot fail to acknowledge the guidance and inspiration of the late Dr. Charles E. Bessey throughout the course of these studies.

PRELIMINARY CONSIDERATIONS

Historical

The literature of the work done upon this problem is meager and widely scattered. As has been noted before, both botanists and foresters have worked in this field, so that papers from widely different sources had to be considered. General observations were found to be much more numerous than results based upon exact investigations. Too often one finds opinions and views upon these questions with but very little data to substantiate

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them. Foresters and botanists, in general, have proceeded on the assumption that light and soil moisture are necessary for germination. They have also noted that germination is accelerated in sand as against a heavier soil like loam or clay. Little has been done to inquire further into these relations. On the whole the effect of habitat factors upon the early development of plants has received more attention than their effect upon germination. In the following historical summary, light in relation to germination and early development of plants will be considered first, since probably more work has been done upon that particular phase of the problem than any other.

One of the oldest notions regarding light and its relation to plant growth is the one concerning the effect of artificial or natural shade upon atmospheric and soil moisture conditions. The forest experiment stations of Europe have long since worked out this relation in the forest, so that to-day these results are more or less well known to all foresters and botanists. Several Americans, working on the effect of artificial shading upon the growth of tobacco, have brought out results similar to those secured in connection with forests. Hasselbring (3) has shown that the transpiration of plants grown in the open is nearly 30 per cent. greater than the transpiration of plants grown under cheese-cloth shade. The transpiration per unit of leaf surface was nearly twice as great in the sun plants as in the shade plants. Stewart (4) records the results of observations made in the course of tobacco experiments in Connecticut on the climate and soil conditions as affected by tents in producing a certain kind of tobacco. He concludes that under the shade of tents the soil retains more moisture, there is a greater relative humidity, and there is a reduction in wind velocity, all resulting in plants which are larger and of more rapid growth as compared to those grown without tents. To sum up the effect of shade it might be stated tersely: it lowers the air and soil temperatures and breaks the action of the wind; these factors increase the humidity of the air and this increased humidity results in less evaporation from the soil and less transpiration from the plant; the final consequence is a greater soil moisture content with its correspondingly good effect upon the growth of the plant.

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The effect of light upon the height growth of forest trees has been used as a basis for determining the relative tolerance of these trees. As early as 1866 Kraft (2) planted a number of different species in the shade of older trees and measured their heights and diameters several years later. Upon this basis Kraft arranged the species according to their tolerance. Nikolsky (2) in 1881 carried on similar experiments with pine and spruce and showed that the greatest length of stem was found in the trees which grew in the shade; the length of the entire plant above ground increased with increase in shade; the length of the main root as well as the number and total length of the lateral roots, however, diminished with increase in shade, while the total length of all roots of plants which grew in great light intensity was greater than the total length of all the roots in the shaded rows. At the Swiss experiment station in 1893 Badoux (2) carried on experiments on eleven tree species with different degrees of shading to determine their behavior in different light intensities and thus determine their tolerance. Fir and spruce had almost the same average height growth at different degrees of shading. With pines, larch, beech, and ash the growth on the contrary decreased in proportion to the shading. In the case of basswood, blue beech, and elm the growth in height was but little affected. The work of Wiesner (2) from 1905 to 1909, in various parts of the world, and of Clements and Pearson in the United States (2) between 1907 and 1909 was only for the purpose of determining the minimum light requirements of species as a basis for scales of tolerance. The last two investigators took numerous readings in the Rocky Mountains and noted the condition of seedlings under various light intensities.

Burns (9) experimenting with white pine under lath shade in the nursery found that shading delayed the time of germination but that the final germination per cent. was about the same in both cases. He likewise raised white pine seedlings in full shade, half shade, and no shade and (at an age which he does not state) measured the length of the hypocotyls, tap roots and lateral root branches. He found the greatest length of hypocotyl in the plants that had been grown in the full shade, the greatest length

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of tap root in plants that had been grown in no shade and the greatest length of lateral roots and total root system in the no-shade plants. This bears out Nikolsky's experiments along the same line. An interesting conclusion reached by Burns is that shade reduces the temperature of the soil and delays the time of germination.

The work of Atterberg (9) which is quoted by Burns is given here for completeness. Atterberg studied the relation of light and temperature to the germination of pine seedlings. He found that at a constant temperature of 23° C. 80 per cent. of the seed germinated in the absence of light and 87 per cent. in the presence of light during practically identical germination periods. Burns concludes from this: "Apparently a high and changing temperature, light, and a moist seedbed are essential to satisfactory germination."

The investigations of Haak (5) and Pittauer (6) have very little bearing upon the problem at hand. The former at the mycological laboratory at Eberswalde studied the influence of season, moisture, temperature, light days and dull, artificial and natural light, color of light, intensity and duration of light, and the influence of chemicals upon the germination of Scotch pine seeds. He found that in lower temperatures germination begins considerably later and proceeds much more slowly that in higher temperatures, but that the final germination per cents. are about the same in either case. He found that certain rays of light were beneficial and certain harmful to germination. Pittauer studied the effect of different degrees of light and extreme temperatures upon the germination of tree seeds of certain European species, viz.: beech, black locust, and various conifers. He found that germination proceeds more rapidly in light than in shade and is most satisfactorily accelerated in diffused light.

Undoubtedly considerable work has been done in the United States by the various forest experiment stations of the Forest Service but these results have not been, as far as my knowledge goes, published. In a very recent article in *Science,* Graves (7) speaks of such work being carried on at the Wind River Forest Experiment Station in Oregon. A recent discovery at this sta-

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tion showed that the seed of *Pinus monticola* of Idaho lies in the duff and litter beneath the mature stands for years and then germinates when the ground is exposed to direct lighting. This is mentioned here, merely as another instance of the many of record in which it is assumed that light is to a large degree responsible for the germination of certain tree seeds.

Practically the only work of any importance on record concerning the effect of soil moisture and soil texture upon the early development of forest trees is that of Tolsky (8). He studied the relative effect of sandy and black soils upon the structure of the root system of Scotch pine. He found on black soils that pine developed principally vertical roots while on sandy soils superficial roots predominate. In rich soils roots are guided in their development by moisture, while in poor soils like sand, activity is directed mainly towards extracting nutrition from the soil. In poor soils nutrition is spread over a large area and in order to get it in sufficient quantities trees need numerous roots. Whatever the cause might be, Tolsky found more lateral roots and more superficial roots in the case of trees grown in sand, and this may be taken as the most significant part of his work.

Before discussing the present investigations, I feel that it would be profitable to briefly summarize the edaphic factors of the habitat with special reference to the physical properties of the soil which play a physiological rôle in the germination of the seed.

Classification and Résumé of Habitat Factors

The complex of climatic, edaphic, and biotic factors which influences the life, growth, and reproduction of a plant is known as its habitat. The study and investigation of habitats as entities avails us very little unless we analyze a habitat into its component parts and investigate each of these parts by itself.

Clements (1) classifies habitat factors into physical and biotic. The former have to do in general with inanimate objects and the latter with human beings and animals. He further divides physical factors into climatic and edaphic. Climatic factors are atmospheric in their nature and the edaphic factors are concerned with

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the soil. He further subdivides climatic factors into humidity, light, temperature, wind, pressure and precipitation. The edaphic factors are subdivided in a similar way into water content, soil composition, soil temperature, altitude, slope, exposure, and surface.

In glancing over this classification it becomes at once obvious that all of these factors cannot affect the plant directly. Many of those enumerated are in themselves very complex in their nature. For example, slope, aspect, altitude, and surface could each be subdivided into component factors, but if this is done it will be seen that they resolve themselves into those factors mentioned above which are not divisible. In other words there are about three master factors which are able to affect plant life directly, and all others are combinations of these. There is no better way to bring out this idea than to give Clements' (1) classification based upon the influence which each of these factors may exert on plant life. He classifies factors into those that have a direct bearing upon plant life, those that have an indirect bearing, and those that have a remote bearing. Direct factors are only those which produce qualitative structural changes in the plant itself. Furthermore, the classification of habitat forms and plant formations is based upon them, which fact merely emphasizes that they are fundamental. Indirect factors are those that affect a formative function of the plant through another factor; and remote factors are those which are physiographic or biotic in nature and must operate through at least two other factors in order to produce a structural change in the plant. This classification is as follows:

Direct Factors	*Indirect Factors*	*Remote Factors*
Water content	Temperature	Altitude
Humidity	Wind	Slope
Light	Pressure	Exposure
	Precipitation	Surface
	Soil composition	
	Soil temperature	

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The germination of seeds depends principally upon edaphic factors, hence climatic factors will receive little attention here except in so far as they condition the former. It is taken for granted that the morphological and the physiological significance of water, light and heat to plant life are too well known to require discussion here, especially since that phase of botany is fundamental in all ecological work.

The water content of the soil is by all odds the most important edaphic factor in determining germination, for while other factors may condition this process to a certain extent, none but water, within certain limits, can prevent it altogether. In a synoptical manner I will briefly call to mind the significance of this master factor in germination and then briefly inquire into the important soil factors and properties that bear directly on the investigations at hand.

The amount of water in the soil has no direct relation to the amount of water which plants can use. At the outset distinction must be made between the different kinds of water in the soil and which of these are available to plant roots. Usually three kinds of water are distinguished, namely: hygroscopic water, capillary water and free water. Hygroscopic water is that water which plants cannot get owing to the enormous film pressure which holds it. It is also known as the amount of water in an air-dry soil. Capillary water is that water, most of which is available to plants and is held against gravity around the soil particles by capillary forces. Free water is that which is not held either as hygroscopic or as capillary water. It is water influenced in its movements by gravity and is therefore called gravitational or hydrostatic water. Clements (1) calls these echard, chresard, and holard respectively. It will be seen then, that the only water available to plants is a part of the capillary water which surrounds every soil particle and fills every small pore space.

The principal factors which influence the amount of soil moisture available (capillary water) to plants are:

1. The amount of water reaching the soil.
2. The catchment of water by the soil.
3. The water-holding capacity of the soil.

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4. The amount of evaporation from the soil.
5. The amount of water withdrawn by other plants.
6. The replacement of loss by capillary movement.
7. The amount lost by seepage, percolation, etc.

Of these factors, only four are important in the present investigations. These are the water-holding capacity of the soil, the evaporation from the soil, the replacement of loss by capillary movement, and the amount lost by seepage and percolation. The water-holding capacity of a soil is determined by soil depth, soil texture, and the amount of organic matter present. In soil texture two factors are important, namely, the size of the soil particles, which affects the surface area of the particles and the amount of pore space in the soil, and the density of arrangement of these particles. It is largely for these reasons that loam will hold more capillary water and will contain more air space than sand or gravel. Evaporation from the soil naturally affects greatly the amount of water available to the plant. This is affected by climatic factors such as temperature, relative humidity, and wind; and by soil factors such as texture, color, depth and the character of the surface. The replacement of the loss of soil water by capillarity depends upon the rise of water from the water table. This rise is conditioned by the degree of saturation of the lower soil layers, the texture of the soil, the height to which the water must be raised and the character of the intervening soil layers. A fine-textured soil like loam or clay is much more favorable in this respect than a coarse-grained soil like sand or gravel, principally on account of its great ability to obtain water from the lower soil layers. The amount of water lost by seepage and percolation depends largely upon the texture of the soil. The coarser the soil the greater is the amount of water that percolates through it and the less is the amount held by capillary forces.

As far as it determines the amount of soil moisture available to plants, soil texture is certainly the most important physical property of the soil and it deserves a foremost consideration in all problems that pertain to the germination of seeds.

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The Germination Process (10, 11, 12, 13)

This period in the life history of the green plant is unique in that the organism is independent of an external food supply and also of all luminous energy. Germination may be called a period of growth without photosynthetic activity, and it terminates at the time the accumulated food in the endosperm is more or less exhausted. During all this time it is without light; it does not require it, but lives in total darkness beneath the surface of the soil. While the seed has no use for light, it does require water, oxygen, and a certain amount of heat in order to germinate successfully. The dependent life of the plant begins at the termination of the process of germination, when the first ray of light strikes the spreading cotyledons. Light sets the photosynthetic mechanism in motion and this marks the beginning of the plant's manufacture of food; henceforth it is dependent upon its environment.

The rôle of water in the germination process is to aid in the transformation of the accumulated nutrient material into food that can be used by the germinating embryo. In other words, this factor is instrumental in taking this sunken capital and transforming it into specie for circulation. But water cannot do this directly; it must act through the agency of certain catylists or enzymes. These enzymes transform insoluble and indiffusible foods into soluble and diffusible ones which in turn move from the endosperm to nourish the embryo.

Water is important to the seed for two reasons; its absence determines the seed's power to live in a dormant condition, which is one of its most important properties. If a seed is not dry it cannot be preserved; we cannot secure good seed in a wet autumn. The second reason why water is important is because of its chemical and mechanical action in germination. Hales at the beginning of the eighteenth century showed that the absorption of water by seeds is generally accompanied by a considerable manifestation of energy, which takes the form of swelling. Chemically water acts as a solvent for the enzymes which render the accumulated foods soluble.

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Practically all the accumulated foods in the endosperm must be transformed by the action of enzymes, which in turn must first be dissolved by water. Starch, which is insoluble in water, is converted by means of the enzyme diastase into a soluble sugar. Throughout germination the quantity of starch in the seed decreases; the starch grains at first corrode and finally dissolve completely. Many albuminoids (simple proteins) are likewise insoluble in water and certain soluble albumens cannot diffuse through membranes. A pepsin-like enzyme which develops during germination acts upon the albuminoids, transforming them into soluble and diffusible forms. Others are changed to crystalloids which after solution diffuse very readily. Fats and oils are likewise insoluble. Certain enzymes during germination decompose oil into its constituents, fatty acids and glycerin, the latter easily soluble in water. It is well known that fatty acids when set free assist the breaking up of oil in water into very fine drops with the formation of an emulsion.

Heat is important in the germination of the seed in that it may accelerate, retard, or even entirely stagnate the processes begun by the action of water. It might well be said that the rapidity of germination depends to a large extent upon heat, since it has the power to modify the action of enzymes. Temperature likewise affects the diffusion of liquids. A considerable part of the heat used in germination is generated by respiration. This process sometimes raises the temperature of the seed as much as 40–50° F. above the surrounding temperature. Certain seeds owe their ability to germinate at very low temperatures (below freezing) to the heat generated during respiration. Certain arctic and alpine plants are able to blossom in the snow for this same reason.

Seeds in water, seeds buried too deep, or seeds surrounded by air deprived of oxygen do not germinate even if other conditions are favorable. In other words, water and heat are of little avail without oxygen. Even before water and heat can act through the agency of the enzymes, in many cases another factor must come into play to release the enzymes. The latest investigations show that the formation of diastase is intimately connected with respiration. In a similar manner respiration supplies the energy

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which oxidizes the fats and oils of the endosperm. It has been noted that the quantity of oxygen absorbed is much greater in the case of fatty seeds, like those of the pines and birches, than in the case of the starchy ones.

It has been known for a long time that seeds lose weight during the process of germination although no solid matter is lost as near as can be determined. If we take a certain quantity of seeds and weigh them both before and after germination, being sure to get the dry weight both times, we find that although the seeds have increased in size, they have lost weight. This is due to the loss of certain elements like carbon and hydrogen. In the process of respiration the carbohydrates in the endosperm are broken down, carbon and hydrogen are lost while the quantity of nitrogen remains practically constant. In the process of respiration, the products of combustion are carbon dioxide and water.

Respiration in the seed is quite different from that in the case of leaves and other green parts of the plant. Seeds are generally not provided with intercellular air spaces, but oxygen penetrates to their interior chiefly by diffusion from cell to cell. Thus it will be seen that the supply of oxygen to the deep-seated cells of the seed is most liable to become insufficient. This of course retards germination. If the supply of oxygen is reduced materially, due to lack of soil aeration, germination may be prevented. The best aerated soils are those that have comparatively large interstitial spaces, like sands and gravels, and the poorest ventilated soils are the heavy loams and clays which are small grained and compact and have minute interstitial spaces. The seeds of different tree species naturally vary as to their soil requirements in this respect. This explains why tree species of sandy habitats germinate so poorly on clay soils.

From what has been said, it will be seen that water, heat, and oxygen are the essentials for germination, and that the lack of any of these factors is sufficient to retard, if not entirely to inhibit the process.

It is a well-known fact that seeds have a power of remaining dormant for a period without affecting their vitality. The power to retain this vitality is due largely to the nature of the seed-coat

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which insulates the embryo from heat, water and air and protects it from mechanical injury. Cottonwoods, willows, elms, soft maples, and white oaks have a very short period of rest. Usually the period is not over six months, but basswood and hornbeam lay over from fifteen to eighteen months. It has likewise been noted that some tree seeds must lay over for a certain period before germination can take place. The common experience of attempting to germinate seeds in mid-winter which have been gathered during the previous fall is proof of this phenomenon. This leads me to a brief discussion of the process of after-ripening as it is called.

Many seeds we know require a long time for germination in spite of the fact that they are surrounded by the proper conditions. During this period it has been found that certain chemical and physical changes take place which are necessary before the seed can germinate. The length of delay is apparently determined by the persistence of the structure of the seed-coat and to the conditions under which the seed is exposed. The term "after-ripening" has come into use to designate the changes in the seed during this period. Eckerson (17) concludes that most cases of delayed germination are due to the exclusion of water or oxygen by the seed coats. But some seeds do not germinate after all coats have been removed and the seed put into germinating conditions, indicating that the delay is due to embryo conditions. It is now certain that some changes within the embryo are necessary for germination. In the case of *Crataegus* used by Eckerson it was found that food is stored in the embryo in the form of fatty oils; neither starch nor sugar is present. A series of metabolic processes takes place in the embryo during the period of after-ripening. At first there is increased acidity accompanied by increased waterholding capacity. There follows an increased activity and production of enzymes and as a result the fats decrease and sugars appear. The appearance of sugars which are soluble and diffusible marks the beginning of the germination of the seed.

All recent investigations both in America and abroad show how extremely complex is the rôle of oxygen in germination. A set

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of conclusions based upon one species of plant apparently may or may not hold for others. Shull's investigations (14, 15, 18) are based mostly on *Xanthium* seeds. In his experiments he finds no evidences of the diffusion of oxygen through an absolutely dry seed coat. This is significant in that it shows an important rôle of water in preceding oxygen in penetrating seed coats. Experimenting with *Crataegus mollis* Davis and Rose (16) find that seeds treated dry or those placed under water do not go through the process of after-ripening. Here again is evidence that both water and oxygen are necessary. These investigators, working on the effects of temperature upon the period of after-ripening, conclude that favorable moisture conditions and temperature conditions shorten the period. Atwood (19) confirms almost all of the conclusions drawn by Eckerson although working on *Avena fatua.* Crocker and Davis (20, 21) worked with water plants and their results totally different than those described for land plants need not be given.

Unfortunately these conclusions are not based upon forest tree seeds. Such investigations have not been undertaken. This phenomenon will probably explain many of the cases of delayed germination which are well known to foresters. It is reasonable to assume that the conclusions based on *Crataegus* would also hold for such fatty seeds like the birches, spruces, hard maples, etc. It is also reasonable to suppose that most tree seeds pass through this period of after-ripening during the winter months; if this is true it explains why it is often impossible to germinate certain tree seeds immediately after they have been gathered.

Method of Attacking the Problem

There are two general methods of determining the causes influencing the behavior of seeds or plants growing under natural conditions. These are the observational and experimental methods. In the observational method we observe the kind of vegetation produced in response to a certain complex of physical factors and seek to find constant relations of one to the other in order to draw conclusions. In the experimental method we may

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either synthetize an artificial environment and proceed to study the plant under definitely measured differences of light and water, or we may measure the physical factors influencing the same plant under various natural conditions. The observational method is ill suited for most work on habitat relations because the habitat involves an extremely variable array of uncontrolled physical factors, and it is practically impossible to determine without actual measurements which factor has the controlling influence and what the relative importance of the others are. The most desirable method for problems which will allow its application is the one in which we synthetize an artificial environment. In this case we keep certain factors constant and measure the variable one; in this way, it is quite obvious, the environment is comparatively easy to analyze. This method, of course, presupposes a greenhouse and on this account is only of limited application.

There is no question that all these methods have their value in their proper places; the choice of one must vary with the problem and the circumstances. The method of measuring the factors influencing the same plant under various natural complexes is the one probably of widest application in the field. The purely observational method, for work on the determination of habitat factors, while of some value when other methods are impossible of application has unsurmountable objections. Observers in various parts have no common basis or standard; their mental equipment and fund of ecological knowledge vary greatly and they may even have very different points of view. Some of these objections might be summed up in the term "personal equation." Another danger in this method is that of applying local observations to large areas, in other words, in generalizing on the basis of too meager observations. The conclusions drawn in the observational method are largely in the nature of opinions modified as indicated above by the personal equation, while the experimental method produces conclusions based upon actual figures which are indisputable and carry the weight of scientifically proven facts.

Another objection to the observational method in determining the effect of habitat factors is that this method studies the effect

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and not the cause of the factors. It is a most significant fact that the same habitat factors do not always produce the same effects upon vegetation even under apparently the same set of conditions. The effect of two habitat factors or groups of factors may be the same so far as the structure and behavior of the plant is concerned, yet upon inquiry into the causes concerned we might find in one case it was due to temperature and in the other to soil moisture. In a similar manner it is known that other factors besides light determine tolerance. In other words the study of the effect of habitat factors upon plants does not always lead us to safe assumptions as to what the underlying cause is. The only safe method in this kind of work is to measure the cause, thus employing a direct method instead of an indirect one.

Methods and Apparatus Used in These Investigations

The investigations herein described were carried on in the middle room of the west greenhouse of the botany department of the University of Nebraska. For the germination studies three series of cultures were used, namely, the light, soil-moisture, and soil-texture series. For the experiments and measurements in connection with the early development of roots and stem a fourth series was added, namely, the soil-depth series. In each series three degrees were used. In the light series open light, medium shade, and dense shade were used; in the soil-depth series shallow, medium deep, and very deep soil was used; in the soil-moisture-content series, dry soil, medium wet soil, and wet soil was employed; and in the soil-texture series loam, sand, and gravel were used. The values of each degree in each case will be given later. As the experiments progressed it was found that the amount of greenhouse space assigned to the work was not sufficient, so that the open light culture, the wet soil culture, and the loam culture were combined into one since these were being run under identical conditions. (For arrangement of cultures see page 33.)

The seeds for these experiments were obtained from any source it was possible to get them. Large orders were sent to almost all large commercial seed houses at one time or another. On the whole the response from these orders was very discouraging. At

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the time the seed was wanted (early fall) many of the seed crops had not been collected. Likewise it took time to determine whether there would be any crops at all in the case of some species. This resulted in delay in getting the work started. By the middle of January eighteen species had been obtained from commercial seedmen and of these only seven produced results that were in any way satisfactory. On the other hand, through the kindness of various members of the Forest Service throughout the United States, twenty-six species were secured and practically all of these produced good results. Due to these facts anyone undertaking experiments of this kind in the future must look a long ways ahead for a good seed supply. The following series of tables gives the source of the seed obtained together with what information was available as to date and place of collection. The nomenclature used here and throughout this report is that used by the Forest Service and is according to Forest Service Bulletin No. 17 by G. B. Sudworth.

SPECIES SUPPLIED BY THE UNITED STATES FOREST SERVICE

Species	Place Collected	Date
Pinus ponderosa	California	?
Pinus ponderosa	Pecos N. F., New Mexico	1913
Pinus ponderosa	Weiser N. F., Idaho	1912
Pinus ponderosa	Harney N. F., South Dakota	1912
Pinus ponderosa	Bitterroot N. F., Montana	1912
Pseudotsuga taxifolia	Pecos N. F., New Mexico	1913
Pseudotsuga taxifolia	Caribou N. F., Idaho	1912
Pseudotsuga taxifolia	Madison N. F., Montana	1911
Pseudotsuga taxifolia	Western Washington and Oregon	1911
Pinus Jeffreyi	Kern N. F., California	1912
Abies concolor	Durango N. F., Colorado	1913
Tsuga heterophylla	Olympic N. F., Washington	1911
Pinus lambertiana	Lassen N. F., California	1910
Libocedrus decurrens	Eldorado N. F., California	1914
Pinus palustris	Florida N. F., Florida	?
Pinus coulteri	Monterey N. F., California	1910
Abies magnifica	Sequoia N. F., California	?
Sequoia washingtoniana	Sequoia N. F., California	1912
Pinus divaricata	Minnesota N. F., Minnesota	1910
Pinus contorta	Arapaho N. F., Colorado	?
Pinus resinosa	Minnesota N. F., Minnesota	1910

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Larix occidentalis	Colville N. F., Washington	1911
Abies lasiocarpa	Priest River, Idaho	1913
Abies grandis	Priest River, Idaho	1913
Picea sitkensis	Coast of Washington	1911
Pinus monticola	Priest River, Idaho	1914

SPECIES SUPPLIED BY COMMERCIAL SEEDMEN OR COLLECTED

Species	Place Collected	Date
Pinus strobus	Canada	1913
Larix europea	Europe	?
Pinus ponderosa	Black Hills, South Dakota	1913
Pinus divaricata	Northern Minnesota	1914
Robinia pseudacacia	Europe	?
Catalpa speciosa	Indiana	1913
Quercus rubra	Michigan	1914
Acer saccharum	Illinois	1914
Liriodendron tulipifera	Ohio	1914
Betula papyrifera	Pennsylvania	1914
Abies balsamea	Maine	1914
Pseudotsuga taxifolia	Colorado	1913
Pinus taeda	Southern states	?
Taxodium distichum	Southern states	?
Liquidamber styraciflua	North Carolina	1914
Acer saccharum	Canada	1914
Acer rubrum	New Hampshire	1914
Fraxinus americana	Indiana	1914
Juniperis virginiana	Missouri River, Nebraska	1914
Gleditschia triacanthos	Lincoln, Nebraska	1915
Pinus monticola	Glacier Park, Montana	1914
Catalpa speciosa	Lincoln, Nebraska	1915

In the body of this report, in order to distinguish the climatic varieties of a species, the name of the state in which the seed was collected is given with the name of the species.

The first planting was done on October 28, 1914. From that time on plantings were made as the seed arrived. The last seeds were planted March 21, 1915. All experiments were conducted between the first date mentioned and May 1, 1915, a period of 184 days. In all cases ample time was allowed for the completion of the process of germination. This time naturally varied with the species. For most species three months was allowed but in the

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case of certain Pacific coast species four months was apparently necessary. Three months ordinarily is plenty time enough; usually if a seed in the forest fails to germinate in that time, it usually does not germinate at all, especially in the west where the dry period sets in after the spring is over.

Ten of the species mentioned in the foregoing tables failed to germinate. These species were *Larix europea, Acer saccharum* (both), *Liriodendron tulipifera, Taxodium distichum, Liquidamber styraciflua, Fraxinus americana,* all of which were supplied by commercial seedmen. If the data regarding the collection of these seeds is bona-fide, their failure to germinate must be explained by the fact that they had not completed their resting period. In the case of *Juniperis virginiana, Gleditschia triacanthos,* and *Pinus monticola,* whose place and date of collection is known absolutely there can be very little doubt as to why they failed to germinate.

The soil used in all cultures (except the sand and gravel) was a garden loam of excellent quality with a mixture of about 25 per cent. of white sand. The mixture was prepared in the greenhouse. This made a very good soil for experimentation purposes. The sand used was common white, quartz sand with but a very small per cent. of hornblende and magnetite. The gravel was the kind used by the large construction companies around Lincoln for concrete work. Mechanical analyses of representative samples of these soils are given elsewhere.

All seeds were planted in rows at a depth which was 2½ times the shortest diameter of the seed as near as this was determinable by the unaided eye. The rows averaged 3 inches apart and about 24 inches in length. In general 200 seeds were used of each species when the seeds were of medium size or smaller; for some of the western pines only 100 were used because of their large size.

The Control of Habitat Factors

As has been pointed out, the only safe way to study the effect of the factors of the habitat upon the life of the plant is to measure one variable factor while all the rest are kept constant.

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This principle is fundamental in mathematics; a single algebraic equation with two unknown quantities cannot be solved. In each of the series used in these investigations it was the intention to have only one variable habitat factor. In this way the study of cause and effect was much more clearly brought out.

The soil moisture determinations were made for four different purposes:

1. As a check upon daily watering in similar cultures.
2. To show the effect of shading on soil moisture content.
3. To show the minimum content in the soil moisture series.
4. To compare soil moisture content in loam, sand, and gravel.

The samples were taken in certain cultures and at intervals varying with the purpose. The samples for the moisture content series of cultures were taken once a week, all others once a month. Each sample consisted of from 50–100 grams of soil, and was taken at depths varying with the development of the plants in the culture. In order to provide against error each sample consisted of from two to five portions taken from spots several decimeters apart, care being exercised that no soil was dug near holes where previous samples had recently been obtained. The samples were always dug between the rows of seedlings. The samples were immediately weighed and dried at a temperature of 95–105° Centigrade to constant weight (24 hours). The per cent. of water was computed upon the dry weight of the soil.

All the cultures except the dry soil and the medium wet soil cultures were watered every evening. As was noted above, when the amount of room for the germination tests became insufficient the number of cultures was reduced from 12 to 10 by eliminating two duplicate cultures. The only check moisture samples which will be considered here are those that have to do with the three cultures which were being operated under identical conditions. Samples taken and recorded hereafter will take care of the other cultures and series. During the time (three months) that these duplicate cultures were run, one set of soil samples was taken as a check to determine whether they were being watered equally. These figures follow:

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CHECK SOIL MOISTURE SAMPLES 11/14/14

Depth 5.0 cm.

Name of Culture	Moisture Per Cent.
Open light	27.9
Wet soil	24.1
Loam	27.7
Deep soil	28.2
Medium depth	28.5
Shallow soil	31.4

These figures, obtained after more than two weeks of daily watering, pretty well indicate the small amount of variation in moisture content which results in a number of cultures under the same conditions.

Light was controlled in the greenhouse by means of shade tents. The east bench of the room was divided into three parts and the portions at the ends of the bench were covered with cheese cloth. The central compartment of the three was not used on account of the shading influence of the tent to the south of it. (See page 33.) The tent intended to develop medium shade was made of a medium grade of cheese cloth, while the tent intended for the dense shade was constructed of a double layer of heavy cheese cloth. The light values developed in these tents and in the full light of the greenhouse as determined by a Clements photometer are given below:

TABLE OF LIGHT VALUES

Date	Time	Open Light	Medium Shade	Dense Shade	Number Readings	Weather
11/21/14	11:30 A.	0.4250	0.1775	.....	5	Clear
11/27/14	12:00 A.	0.4040	0.1467	0.0216	3	Clear
Average.....	.....	0.4145	0.1621	0.0216	.	.....

These values are based upon full sunlight just outside of the greenhouse. These tables indicate that full greenhouse light is approximately ½ of full daylight and that the medium and dense shade tents have values approximately ⅙ and 1/50 of full daylight respectively.

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It is quite natural to wonder how these values compare with values that have been obtained in the woods. Probably the comparison of the light values obtained in the dense shade with some of the lowest values obtained in the woods would be most interesting. Clements (2) found light values from 0.12 to 0.05 under mature lodgepole pine in Colorado. He observed that Douglas fir occurred very rarely in densities below 0.05. Wiesner found the same value in this case. Pearson in Arizona found that western yellow pine seedlings grow fairly well in a light intensity from 0.309 to 0.414. White fir was found in good condition in light intensities of from 0.027 to 0.068 and healthy young growth of Engelmann spruce was found in intensities of from 0.033 to 0.062. In Oregon Pearson found such tolerant species as alpine fir, Engelmann spruce, western hemlock, and Lowland fir growing in light intensities from 0.021 to 0.029. The western larch however showed only poor development in a light intensity of 0.353. This will be sufficient to indicate that the light in the dense shade tent compares with some of the lowest light intensities that have been measured in our western forests. In this connection it is interesting to note that white pine, black locust, red oak, and western yellow pine lived for two to four mouths in the dense shade tent, as is evidenced by the fact that stem and root measurements were taken on these species during the last days of these investigations.

In connection with the light experiments a very important fact soon became evident. In spite of the fact that all three cultures were watered every evening at the same time and in the same degree, it soon became evident from mere observation that the top layer of soil by the following evening had dried out to very different degrees in the three cultures. The open light culture was noticeably the driest and the dense shade culture the moistest so far as the top layer was concerned. This fact led to taking systematic moisture samples to determine the exact difference in moisture content. These samples were taken once a month, three evenings in succession and these readings were averaged into one reading. The table of soil moisture contents is given below:

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TABLE OF SOIL MOISTURE CONTENT IN LIGHT CULTURES IN PER CENT.
Depth 2 cm.

Dates	Open Light	Medium Shade	Dense Shade
11/10–12	12.3	15.3	19.8
12/13–15	12.0	19.0	19.3
1/4 –6	6.1	15.7	18.0
2/14–16	14.0	16.6	21.3
3/14–16	14.4	17.0	21.3
4/15–17	10.3	17.2	19.7
Average	11.5	16.8	19.9

Soil depth was comparatively easily controlled, either by only partially filling the flats with soil or by using deeper boxes. This was done and the depths used were as follows:

Shallow soil ..... 4.0 cm.
Medium deep soil ..... 9.0 cm.
Very deep soil ..... 30.0 cm.

The depth of the medium soil was the depth of all the other cultures used in the light, soil moisture, and soil texture experiments. No attempt was made to measure the soil moisture content periodically in the soil depth cultures, except as noted in checking up the watering of the cultures.

Soil moisture was controlled in the soil moisture experiment by watering the cultures at different intervals. The wet culture was watered every evening, the medium wet culture was watered every Wednesday noon and Saturday evening and the dry soil culture was watered only every Saturday evening. The soil samples that were taken were secured just before watering and were taken at first every Wednesday noon and every Saturday evening and later only every Saturday evening. Thus the soil samples represent the minimum water content of the soil at the end of one day, at the end of three and one half days, or at the end of seven days. In the following table are given the soil moisture per cents as taken at various depths according to the stage of development of the majority of the seeds or plants in the cultures concerned.

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MINIMUM SOIL MOISTURE CONTENT IN SOIL MOISTURE CULTURES

Date	Depth, Cm.	Dry Culture, Per Cent	Medium Wet Culture, Per Cent	Wet Culture, Per Cent
11/4	0–5	6.4	10.5	23.0
11/7	0–5	4.0	13.7	30.0
11/11	0–5	4.6	5.0	25.0
11/14	0–5	7.2	14.1	24.1
11/21	0–5	7.7	17.1	21.1
11/28	0–5	6.7	13.8	22.3
12/5	0–5	6.1	12.4	24.3
12/12	0–5	8.5	16.6	23.3
12/19	0–5	5.2	12.1	26.5
12/26	0–9	4.3	9.4	27.5
1/2	0–9	6.8	11.8	24.7
1/9	0–5	5.7	15.7	40.0
1/16	0–5	5.1	12.5	36.6
1/23	0–5	3.0	6.3	17.9
1/30	0–5	3.2	7.1	18.8
2/6	0–9	4.7	12.4	20.7
2/13	0–5	4.3	....[1]	19.0
2/20	0–5	6.3	13.8	23.3
2/27	0–5	5.4	14.1	38.3
3/6	0–5	4.0	9.4	27.7
3/13	0–5	3.1	6.7	19.8
3/20	0–5	3.5	9.3	19.6
3/27	0–5	4.5	15.6	21.7
4/3	0–5	4.5	12.4	19.8
4/10	0–5	5.9	14.0	30.8
4/17	0–5	3.5	8.0	23.8
4/24	0–5	4.0	12.4	20.7
Average	....	5.1	11.8	23.9

Soil texture was controlled by the use of cultures of loam, sand, and gravel. Soil texture affects principally the moisture content and the air content of the soil, hence careful analyses to determine both relations were made. The following moisture determinations were made for sand, loam and gravel, which show the amount of hygroscopic water, the volume of pore space, and the amount of capillary water in each of these soils:

TABLE OF SOIL DETERMINATIONS

Texture of Soil	Hygroscopic Water, Per Cent	Volume of Pore Space in Per Cent	Capillary Water, Per Cent
Gravel, fine		36.54	5.4
medium	0.14	39.34	5.0
coarse	....	41.14	2.8
average	....	39.04	4.4
Sand	0.11	33.51	16.6
Loam	0.92	53.32	38.0

[1] Lost by accident in the soil oven.

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The per cent. of hygroscopic water in the soils was the amount of moisture the soils held at room temperature. The amount of pore space in the soils was equivalent to the total amount of water the soils would hold. This would also be the amount of air in the soil when air dry. In determining the amount of pore space the soil used was air dry, hence the amount of hygroscopic water in the soil had to be added to the amount of pore space. The amount of capillary water was the amount of water the soils held against gravity. The same soils were used in all three experiments and the samples consisted of about 150 grams each except in the volume determinations in which 100 cubic centimeters of soil were used in each case. This table shows very strikingly the water and air relations in these soils. The great amount of air in gravel when it is at its maximum capillary water content is also shown approximately.

The mechanical analyses of representative samples of these soils which were kindly furnished by the department of agronomy of the University of Nebraska are given below:

MECHANICAL ANALYSIS OF SOILS

Separate	Diameter, Mm.	Loam	Sand	Gravel
Stones	Above 3	.....	.....	38.639
Coarse gravel	3–2	.....	.....	40.382
Fine gravel	2–1	7.936	21.045	14.051
Coarse sand	1–.5	11.771	29.418	4.245
Medium sand	.5 –.25	8.197	21.709	1.062
Fine sand	.25 –.1	11.392	25.708	0.770
Very fine sand	.1 –.05	6.182	1.074	}
Silt	.05 –.005	21.704	} .346	} 0.268
Clay	.005 and less	26.566		
Volatile matter	.....	6.252	0.700	0.583
Total	.....	100.000	100.000	100.000

Besides these determinations soil samples were taken once a month to determine how much moisture these soils held at the end of a day in the cultures in the greenhouse. These results bear out the findings in regard to capillary water held by the soils shown in a preceding table. These moisture contents are given below:

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SOIL MOISTURE CONTENT TWENTY-FOUR HOURS AFTER WATERING
Depth 5.0 cm.

Date	Loam, Per Cent	Sand, Per Cent	Gravel, Per Cent
11/14	27.7	4.3	2.4
12/15	25.6	5.4	2.1
1/15	25.1	4.8	2.5
2/15	26.1	5.0	2.0
3/15	28.7	5.1	2.4
4/15	27.4	4.9	1.9
Average	26.8	4.9	2.2

The temperature and humidity of the air were determined by a hydrothermograph which was checked every Monday morning by means of a cog psychometer and humidity tables (the barometric pressure used was 29 inches). The record sheets were summarized and the results for the entire period are given below by weekly averages:

Week Ending	Temperature, Degrees Fahr.				Relative Humidity, Per Cent		
	Min.	Max.	Weekly Range	Weekly Mean, 2 Hr.	Min.	Max.	Weekly Mean, 2 Hr.
November 1	60	100	40	71.7	18	78	49.0
8	53	99	46	67.9	34	93	69.4
15	52	94	42	67.8	20	90	64.0
22	49	90	41	66.6	29	75	54.9
29	54	90	36	67.2	21	75	55.9
December 6	59	89	30	70.2	32	84	60.7
13	59	87	28	69.7	37	66	55.0
20	52	83	31	67.8	38	62	48.9
27	51	88	37	67.0	35	57	48.8
January 3	56	93	37	72.9	34	69	52.8
10	52	89	37	67.3	41	79	64.7
17	54	85	31	64.6	30	76	64.1
24	47	96	49	65.4	39	75	58.5
31	53	88	35	64.6	43	82	65.7
February 7	53	98	45	70.4	33	68	54.5
14	57	98	41	68.4	38	78	62.2
21	52	95	43	61.5	35	85	71.7
28	55	98	43	64.9	25	65	54.0
March 7	57	100	43	63.2	21	60	53.7
14	54	98	44	65.5	28	65	54.6
21	59	100	41	67.4	22	63	50.5
28	54	100	46	63.7	28	83	62.0
April 4	53	100	47	66.6	23	88	55.7
11	55	100	45	64.5	23	61	47.2
18	47	100	53	64.6	18	85	49.9
25	49	100	51	73.2	24	90	68.3
May 2	61	100	39	75.0	18	92	63.0

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Soil temperature was not measured. With the air temperature at an optimum point during the entire experiment it is reasonable to assume that the soil temperatures were likewise always at an optimum, at least they were never at such a low nor at such a high point so as to affect materially the germination of the seeds or the growth of the seedlings.

Notes on Damping-Off

No special investigations were conducted to determine what species were most affected and what conditions of light, moisture, and soil were most favorable for the development of this group of fungous diseases. This part of nursery practice is a problem of no small importance in itself and the only data here given is that which had to be taken in connection with this series of investigations. Therefore these are merely notes and suggestions, which, while conclusive as far as they go, must be substantiated in the future to be of any permanent value.

It was found that the pines were most affected. *Pinus divaricata* at the end of five weeks was affected most. About 15 separate cultures of 200 seeds each of this species were started and most of these showed more or less serious effects of the disease. Several cultures of *Pinus resinosa* failed after six weeks. *Pinus palustris* damps off in loam before it really gets its crown above ground. In this case the loss was reduced in the sand and gravel cultures. Both the New Mexico and South Dakota varieties of *Pinus ponderosa* after five weeks damped off considerably, leaving only from 10–25 per cent. of the original stand. The following is a list of species in the order in which they were affected in loam under normal conditions of light and water. The first mentioned were affected most:

Pinus divaricata	*Pinus ponderosa* (N. M.)
Pinus resinosa	*Robinia pseudacacia*
Pinus palustris	*Pinus strobus*
Pinus ponderosa (S. D.)	*Pinus taeda*

It appears that the seeds of trees of certain habitats when germinated in soils or under conditions different from those obtaining in their natural environment are affected worst. These habitats are:

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1. Sandy soils
   Pinus divaricata
   Pinus resinosa
   Pinus palustris
   Pinus taeda
2. Dry habitats
   Pinus ponderosa (S. D.)
   Pinus ponderosa (N. M.)
3. Poor soils
   Robinia pseudacacia.

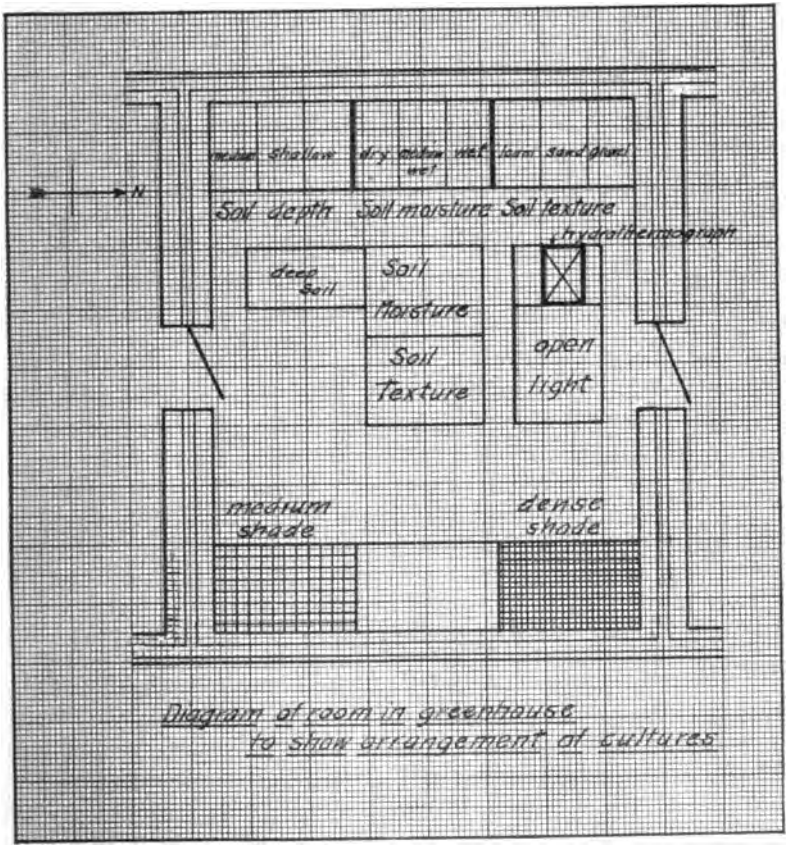

Diagram of room in greenhouse to show arrangement of cultures

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Species that seemed to be affected most were those from the Black Hills and New Mexico and those affected least were those from the Pacific coast. Intermediate between these were those species obtained from Montana and Idaho. The coast species affected most was *Sequoia washingtoniana. Pseudotsuga taxifolia* was much less affected than *Pinus ponderosa* taking into account all the varieties of each.

The conditions and cultures which were favorable to damping-off are of interest in that they emphasize many points already known about this part of the subject. Loam is more dangerous than sand or gravel due to its moisture retentiveness. The shade cultures were more affected than the open light due to a greater soil moisture content in the upper layers of soil. The moist cultures were affected more than the dry ones and the shallow soil cultures more than the deep soil ones due to a greater amount of soil water per unit of volume of soil. Humous soils, soils with decaying vegetable matter, and manure soils should be avoided because they contain myriads of fungus spores. The data for *Pinus divaricata* is given as representative of the three worst affected species. The per cents. given below are those of the number of plants killed (out of the total number that germinated) within five weeks after planting the seed. Two hundred seeds were planted in each culture:

Pinus divaricata KILLED BY DAMPING-OFF

Light Cultures	Soil Moisture	Soil Depth	Soil Texture
Open.....35%	Dry soil..... 0%	Deep..... 8%	Loam.....35%
Medium.....26%	Medium soil...24%	Medium.....35%	Sand..... 1%
Dense.....90%	Wet soil.....35%	Shallow.....61%	Gravel..... 0%

THE EFFECT OF HABITAT FACTORS UPON GERMINATION

This problem was undertaken because it was felt to be of fundamental significance not only to silviculture but to ecology as well. Not only was it desired to throw more light upon some of the phases of this problem that had already been partly worked out and to modify, if necessary, some conclusions that have been drawn, but it was my intention to throw some light upon phases

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of it that had never been attacked. Some of the questions that are immediately called to mind by a mere statement of the problem are: Does light affect germination in any way? Does light affect the germination of tolerant and intolerant species differently? How does soil moisture content affect germination? Do drought-enduring species and moisture-loving species behave alike in this respect? What is the effect of soil texture upon germination? Has the amount of air or oxygen in the soil any significance in germination? Since soil texture affects mainly the moisture content of the soil, does soil texture affect drought-enduring species in the same way as moisture-loving species?

The data collected upon the effect of habitat factors on germination will be presented in four parts. The effect of light, soil moisture, and soil texture will be taken up in the order named and following this there will be given a résumé of the relative effect of all habitat factors. The three most important points to be noted in germination, are the number of days it took until germination began, the total number of days in the germination period, and the final germination per cent. The rate of germination is shown by curves for certain representative species. The length of the germination period was taken as the total number of days during which any seeds germinated. Records were kept long after germination ceased, so that the germination period was ended at the time the last seed germinated. To give data as to the period of greatest activity involves certain arbitrary standards and this method, though tried in compiling the present data, was abandoned. The effect of light, soil moisture, and soil texture upon the periods of greatest activity is best shown by the curves offered for certain representative species.

The original data was taken by two-day periods. Every other day the number of seeds that germinated were counted and recorded. In most cases these were immediately pulled up; but where growth measurements were to be taken later the seedlings were allowed to grow.

The first three tables show the effect of light upon the germination of eastern species, Rocky Mountain species, and Pacific coast species respectively. Three sets of figures are given under each

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degree of light, namely, the number of days which elapsed before germination began, the number of days in the germination period, and lastly the final germination per cent.

The number of seeds used of each species in each culture made was as follows: 100 seeds each of *Catalpa speciosa, Acer rubrum, Gleditschia triacanthos, Pinus taeda, Pinus ponderosa* (Idaho), *Abies grandis, Abies lasiocarpa, Pinus ponderosa* (Mon.), *Pinus ponderosa* (Harney), *Pinus ponderosa* (Calif.), *Pinus jeffreyi, Pinus lambertiana, Pinus coulteri, Abies magnifica,* and *Pseudotsuga taxifolia* (Wash.); 25 seeds of *Quercus rubra,* 400 of *Betula papyrifera,* and 200 seeds of all other species.

When a number of check cultures were combined as was noted previously it became necessary to average the results obtained in several cultures under the same set of conditions. Thus the check cultures used in each series show the same data in every case. Three cultures of each of the following species were averaged together: *Catalpa speciosa* (Ind.), *Pinus strobus, Quercus rubra, Pinus divaricata, Robinia pseudacacia, Betula papyrifera, Pinus ponderosa* (S. D.), *Pseudotsuga taxifolia* (N. M.), *Pinus ponderosa* (N. M.), and *Pinus ponderosa* (Calif.). Two cultures of each of the following species were averaged together: *Pinus palustris, Pinus resinosa, Pinus jeffreyi, Pinus lambertiana,* and *Pinus coulteri.* All other species in the check cultures were planted but once.

In Table I 10 species out of a total of 14 germinated in the dense shade before they did in the open light culture. Only one species, *Pinus palustris,* germinated first in the open light, one species, *Gleditschia triacanthos,* did not germinate in the open light at all, and two species germinated simultaneously in all three cultures. *Pinus strobus* germinated 8 days earlier in the dense shade than in the open light, *Pinus divaricata* 2 to 4 days, *Pinus resinosa* 10 days, *Pinus taeda* 2 days, *Catalpa speciosa* 2 days, *Quercus rubra* 14 days, *Robinia pseudacacia* 2 days, and *Acer rubrum* 4 days.

In 9 cases the germination period is longer in the dense shade than in the open light and, considering the shade cultures together,

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11 species show a longer germination period in the shade than in the light. The other three species did not germinate sufficiently to make a conclusion possible.

TABLE I

THE EFFECT OF *Light* ON GERMINATION

Eastern Species

Species	Open Light			Medium Shade			Dense Shade		
	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus strobus	22	50	10.7	16	54	11.5	14	26	8.0
Pinus divaricata	12	32	54.5	10	26	63.5	10	38	73.5
Pinus divaricata (F. S.)	14	20	39.5	14	26	37.0	10	24	46.5
Pinus resinosa	24	16	30.5	16	24	50.0	14	14	74.5
Pinus palustris	31	53	10.5	32	82	12.0	32	62	5.5
Pinus taeda	34	6	19.0	34	6	33.0	32	8	33.0
Abies balsamea	18	30	11.0	18	38	10.0	18	36	8.0
Catalpa speciosa	18	1	1.0	0	0	0.0	16	1	1.0
Catalpa speciosa (Neb.)	16	12	91.0	14	20	92.0	14	14	88.0
Quercus rubra	40	28	28.0	30	18	12.0	26	42	12.0
Robinia pseudacacia	8	16	28.8	6	18	29.0	6	18	33.5
Betula papyrifera	34	1	1.0	34	1	2.0	34	1	1.0
Acer rubrum	18	30	17.0	16	34	15.0	14	34	16.0
Gleditschia triacanthos	0	0	0.0	6	2	2.0	6	2	2.0

Three species had a higher germination per cent. in the open light than in either of the shade cultures. Four showed the highest per cent. in the medium light and six in the dense shade. The greatest difference was shown in the case of *Pinus resinosa* whose germination per cent. was almost two and one half times greater in the dense shade than in the open light culture.

The germination curves of *Pinus resinosa* and of *Pinus divaricata* are given on page 38. These are representative of the effect that light has upon germination. These curves show a greater germination per cent. in the dense shade culture, a more rapid rise of the germination curve in the dense shade and that germination begins sooner in the shade than it does in the light.

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THE EFFECT OF *Light* UPON GERMINATION

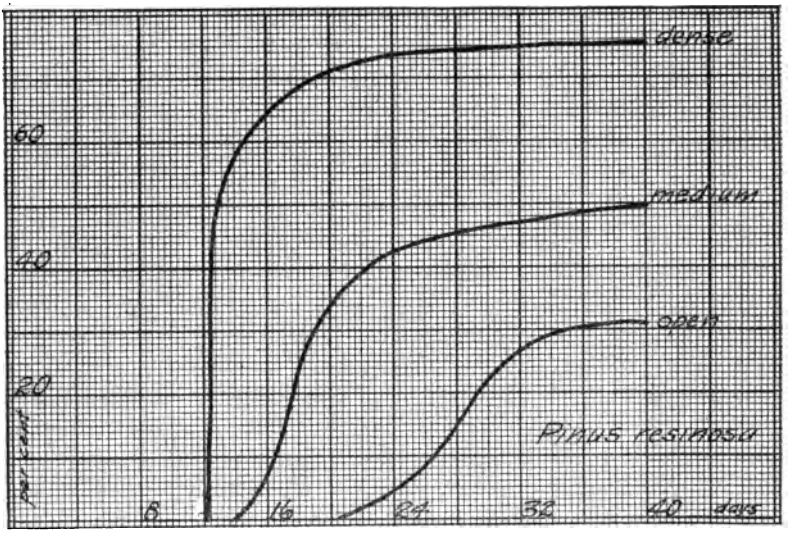

FIG. 1. The germination curves of *Pinus resinosa.*

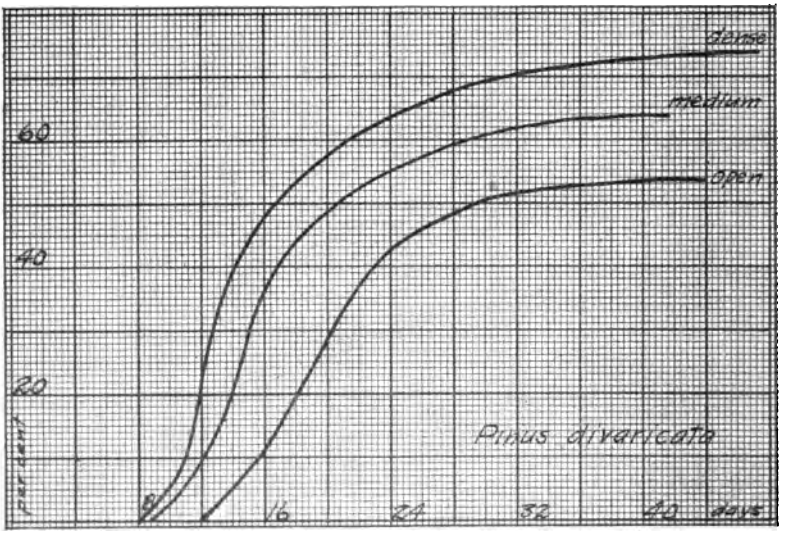

FIG. 2. The germination curves of *Pinus divaricata.*

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TABLE II

THE EFFECT OF *Light* ON GERMINATION

Rocky Mountain Species

Species	State	Open Light			Medium Shade			Dense Shade		
		Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus ponderosa	S.D.	10	32	58.0	10	22	56.5	10	34	58.5
Pinus ponderosa	Harney	14	14	52.0	8	26	58.0	8	26	63.0
Pinus ponderosa	N.M.	14	40	56.0	12	32	82.0	10	12	79.0
Pseudotsuga taxifolia	N.M.	12	26	63.0	10	12	69.0	10	16	65.0
Pseudotsuga taxifolia	Colo.	12	42	91.0	12	36	73.5	8	36	82.0
Abies concolor	Colo.	24	50	38.0	18	56	54.0	14	60	56.0
Pinus contorta	Colo.	14	80	22.0	16	70	7.5	14	72	3.5
Pinus ponderosa	Mon.	18	12	10.0	18	54	15.0	10	8	9.0
Pseudotsuga taxifolia	Mon.	14	34	20.5	12	32	15.5	12	44	35.0
Pseudotsuga taxifolia	Idaho	18	30	20.5	16	64	49.0	10	64	50.0
Pinus ponderosa	Idaho	36	52	42.0	24	66	52.0	14	82	43.0
Abies grandis	Idaho	36	36	4.0	22	62	16.0	22	60	10.0
Abies lasiocarpa	Idaho	30	30	6.0	26	50	7.0	22	28	6.0
Pinus monticola	Idaho	24	50	22.5	16	58	20.0	14	60	36.5

In Table II 12 species out of a total of 14 germinated first in the dense shade, the other two germinated simultaneously in the dense shade and open light. The number of days difference between the two cultures varied from 2 to 22 days. *Pinus ponderosa* (Harney) germinated 6 days earlier in the dense shade than in the open light, *Pinus ponderosa* (N. M.) 4 days, *Pseudotsuga taxifolia* (N. M.) 2 days, *Pseudotsuga taxifolia* (Colo.) 4 days, *Abies concolor* 10 days, *Pinus ponderosa* (Mon.) 8 days, *Pseudotsuga taxifolia* (Mon.) 2 days, *Pseudotsuga taxifolia* (Idaho) 8 days, *Pinus ponderosa* (Idaho) 22 days, *Abies grandis* 14 days, *Abies lasiocarpa* 8 days, and *Pinus monticola* 10 days. The medium shade cultures in most cases represent a condition intermediate between the open light and dense shade.

In 10 species out of 14 the germination period was longer in the shade than in the light. In 6 species the germination per cent. was higher in the dense shade than in either of the other two cultures and in 12 cases out of 14 the highest per cent. was in either of the two shade cultures as against the light culture. In other

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THE EFFECT OF *Light* UPON GERMINATION

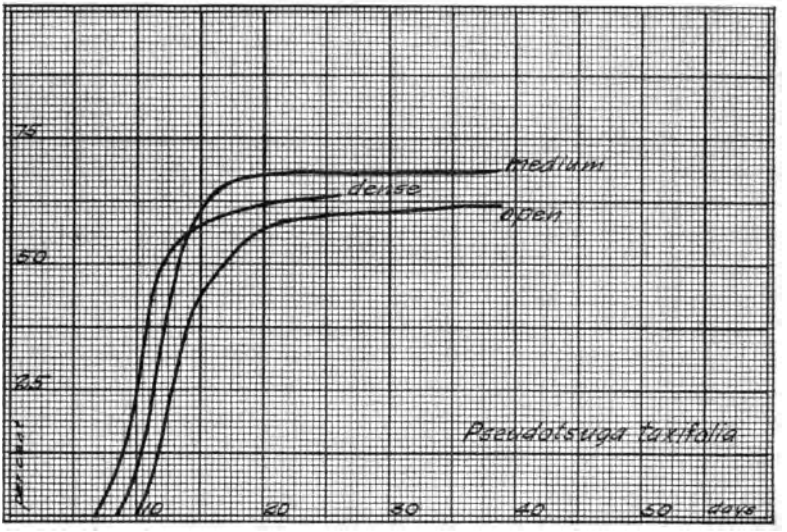

FIG. 1. The germination curves of *Pseudotsuga taxifolia* (N. M.).

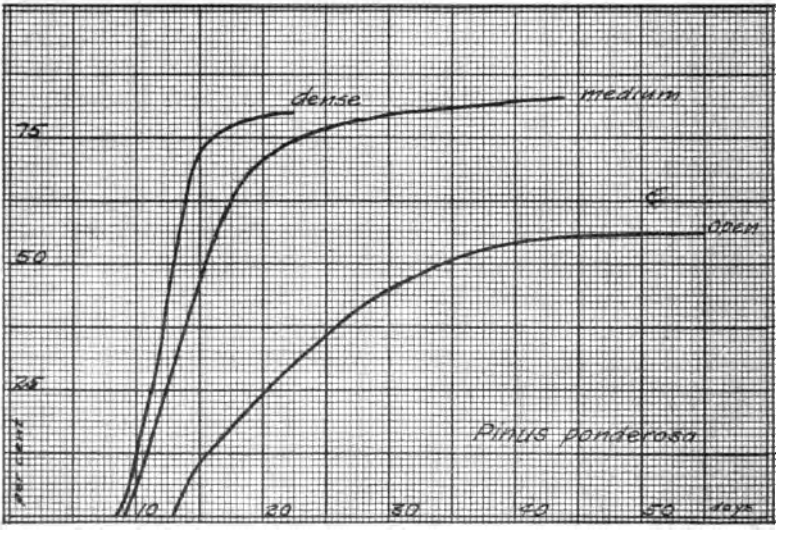

FIG. 2. The germination curves of *Pinus ponderosa* (N. M.).

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words, only 2 species had a higher germination per cent. in the open light than in the shade.

On page 40 are given the germination curves of the two New Mexico species, *Pinus ponderosa* and *Pseudotsuga taxifolia.* While these do not show a higher germination per cent. in the dense shade than in the open light they show the characteristic rapid rise of the shade curves and the fact that germination begins earlier in the shade than in the light.

TABLE III

THE EFFECT OF *Light* ON GERMINATION

Pacific Coast Species

Species	Open Light			Medium Shade			Dense Shade		
	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus ponderosa (Calif.)	42	67	61.0	22	92	62.0	22	62	42.0
Pinus jeffreyi	31	77	22.0	22	84	14.0	20	54	17.0
Pinus lambertiana	70	36	2.5	76	20	4.0	70	24	7.0
Pinus coulteri	52	41	15.5	54	30	18.0	52	62	23.0
Abies magnifica	44	52	18.0	24	54	30.0	36	54	10.0
Libocedrus decurrens	29	73	6.0	24	18	4.0	16	52	9.0
Sequoia washingtoniana	16	18	7.0	16	6	5.5	14	14	8.5
Tsuga heterophylla	66	1	0.5	0	0	0	0	0	0
Picea sitkensis	22	60	22.5	18	64	34.0	14	36	38.0
Larix occidentalis	0	0	·0	72	1	0.5	70	1	0.5
Pseudotsuga taxifolia (Wash.)	22	28	6.0	22	54	13.0	14	62	22.0

Out of the 11 Pacific coast species listed in Table III, 7 germinated in the dense shade before they did in the open light culture, 2 germinated simultaneously in the light and shade and 2 species did not germinate sufficiently to warrant conclusions. *Pinus ponderosa* (Calif.) germinated 20 days earlier in the dense shade than in the light, *Pinus jeffreyi* 11 days, *Abies magnifica* 8 days, *Libocedrus decurrens* 13 days, *Sequoia washingtoniana* 2 days, *Picea sitkensis* 8 days and *Pseudotsuga taxifolia* (Wash.) 8 days.

Six species showed longer germination periods in the shade, three in the open light, and two species did not germinate sufficiently to be considered. Only one species, *Pinus jeffreyi,* showed a higher germination per cent. in the open light, two species showed

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THE EFFECT OF *Light* UPON GERMINATION

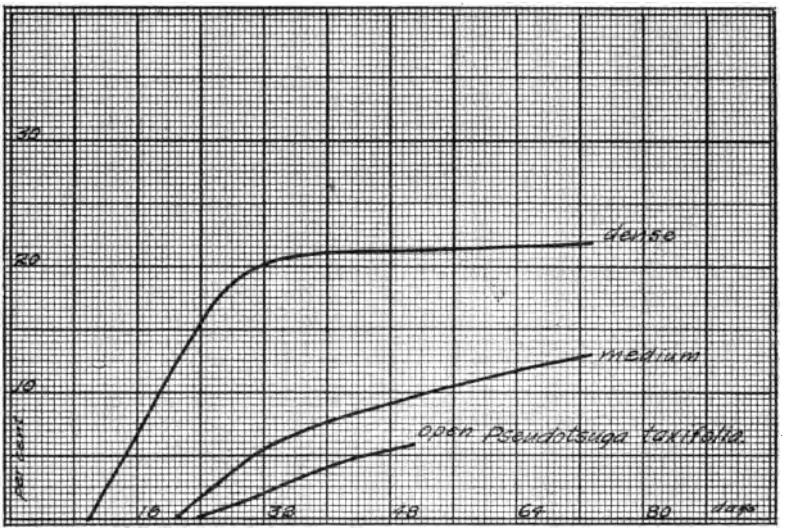

FIG. 1. The germination curves of *Pseudotsuga taxifolia* (Wash.).

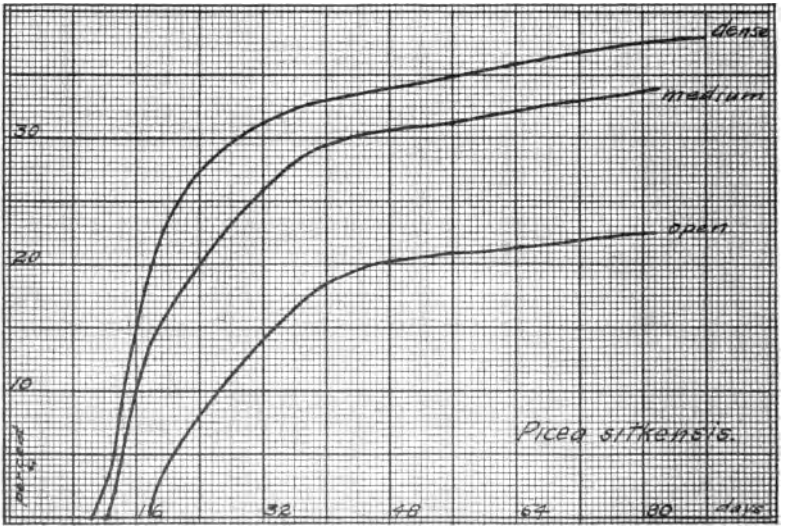

FIG. 2. The germination curves of *Picea sitkensis.*

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a higher per cent. in the medium shade, and six a higher per cent. in the dense shade than in the other cultures.

On page 42 are given the germination curves of *Pseudotsuga taxifolia* (Wash.), and *Picea sitkensis*. Both sets of curves show that germination begins sooner, the curve rises more rapidly and the final germination per cent. is higher in the case of seeds germinated in the shade as compared to light.

TABLE IV

THE EFFECT OF *Soil Moisture* ON GERMINATION

Eastern Species

Species	Dry Soil			Medium Wet Soil			Wet Soil		
	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus strobus	—	—	—	30	34	8.0	22	50	10.7
Pinus divaricata	40	24	10.0	14	50	53.5	12	32	54.5
Pinus divaricata (F. S.)	28	12	7.5	22	18	4.0	14	20	39.5
Pinus resinosa	68	1	2.5	24	40	49.0	24	16	30.5
Pinus palustris	—	—	—	36	50	6.0	31	53	10.5
Pinus taeda	—	—	—	—	—	—	34	6	19.0
Abies balsamea	—	—	—	22	22	12.0	18	30	11.0
Catalpa speciosa	—	—	—	—	—	—	18	1	1.0
Catalpa speciosa (Neb.)	—	—	—	22	6	4.0	16	12	91.0
Quercus rubra	—	—	—	—	—	—	40	28	28.0
Robinia pseudacacia	10	30	15.0	8	32	32.0	8	16	28.8
Betula papyrifera	—	—	—	—	—	—	34	1	1.0
Acer rubrum	24	1	3.0	24	26	12.0	18	30	17.0

Tables IV, V, and VI consider the same species as the three preceding tables from the standpoint of soil moisture instead of light.

In Table IV in practically every case where a comparison is possible germination started in the wet soil culture, and was delayed as the soil moisture content was reduced. Also the germination period is shortened with decrease in soil moisture. The final germination per cent. in every case but one was highest in the wet soil. *Pinus resinosa* showed the highest per cent. in the medium wet soil.

This table separates the species into classes based upon their ability to germinate in dry soil, medium wet soil, or wet soil.

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THE EFFECT OF *Soil Moisture* UPON GERMINATION

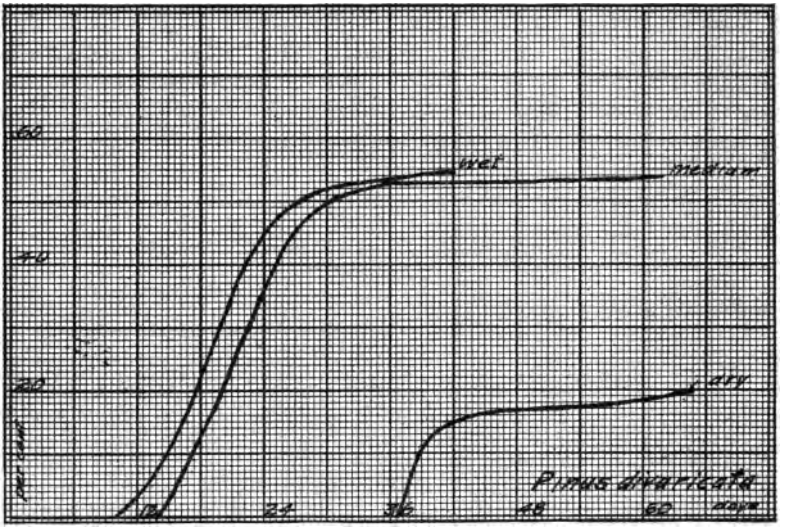

FIG. 1. The germination curves of *Pinus divaricata.*

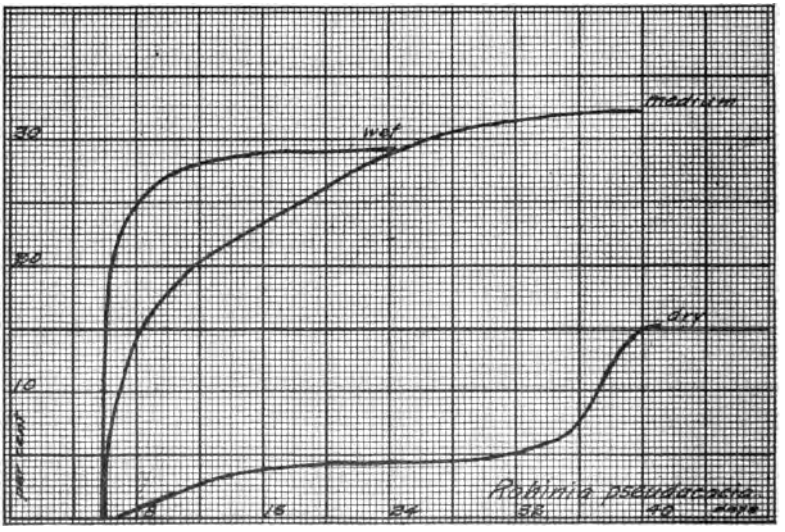

FIG. 2. The germination curves of *Robinia pseudacacia.*

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According to that classification the most drought enduring are *Pinus divaricata, Pinus resinosa, Robinia pseudacacia,* and *Acer rubrum.* It is rather unusual to find *Acer rubrum* in this category but the seed has such a thin seed coat that water absorption is easier than in the case of a thick-coated seed. The intermediate species are *Pinus strobus, Pinus palustris, Abies balsamea,* and *Catalpa speciosa* (Neb.). Among what might be called the moisture loving species are found *Pinus taeda, Catalpa speciosa* (Ind.), *Quercus rubra* and *Betula papyrifera.*

On page 44 are given the germination curves of *Pinus divaricata* and *Robinia pseudacacia.* These sets of curves show that as soil moisture decreases the beginning of germination is delayed, the germination curve rises less rapidly and the final germination per cent. is decreased.

TABLE V

THE EFFECT OF *Soil Moisture* ON GERMINATION

Rocky Mountain Species

Species	State	Dry Soil			Medium Wet Soil			Wet Soil		
		Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus ponderosa	S.D.	26	26	26.0	12	36	48.0	10	32	58.0
Pinus ponderosa	Harney	34	6	8.0	22	18	17.0	14	14	52.0
Pinus ponderosa	N.M.	22	18	39.5	20	16	61.0	14	40	56.0
Pseudotsuga taxifolia	N.M.	12	6	5.5	12	44	54.0	12	26	63.0
Pseudotsuga taxifolia	Colo.	14	24	9.5	12	42	60.5	12	42	91.0
Abies concolor	Colo.	—	—	—	80	26	12.0	24	50	38.0
Pinus contorta	Colo.	—	—	—	20	66	3.5	14	80	22.0
Pinus ponderosa	Mon.	—	—	—	18	58	6.0	18	12	10.0
Pseudotsuga taxifolia	Mon.	—	—	—	18	26	12.0	14	34	20.5
Pseudotsuga taxifolia	Idaho	24	1	0.5	20	32	6.5	18	30	20.5
Pinus ponderosa	Idaho	90	8	5.0	14	72	21.0	36	52	42.0
Abies grandis	Idaho	—	—	—	66	10	3.0	36	36	4.0
Abies lasiocarpa	Idaho	—	—	—	84	1	1.0	30	30	6.0
Pinus monticola	Idaho	48	1	0.5	18	38	9.0	24	50	22.5

As in the preceding table, Table V shows that the beginning of germination is delayed in most cases and that the germination period is considerably shortened with the decrease of soil moisture content. Only 1 species, *Pinus ponderosa* (N. M.) showed a higher germination per cent. in the medium wet soil than in the wet soil, all other species show a higher per cent. in the wet soil.

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THE EFFECT OF *Soil Moisture* UPON GERMINATION

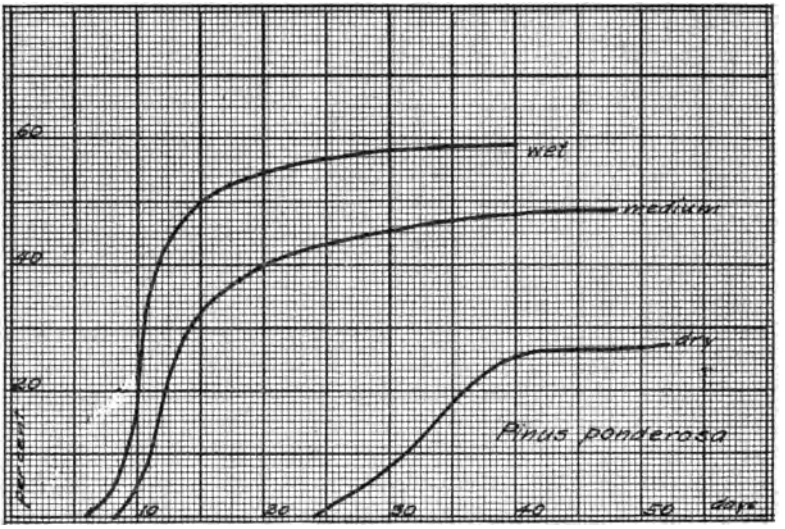

FIG. 1. The germination curves of *Pinus ponderosa* (S. D.).

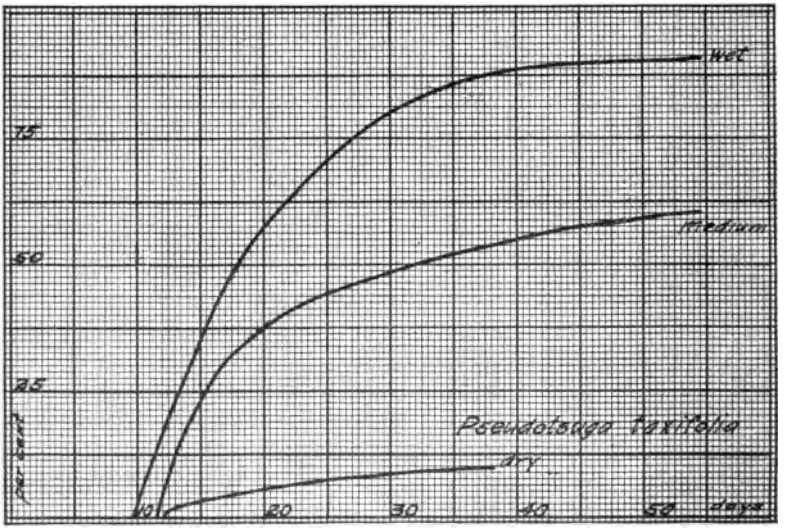

FIG. 2. The germination curves of *Pseudotsuga taxifolia* (Colo.)

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It is evident from this table that the two most drought enduring species are *Pinus ponderosa* (S. D.) and *Pinus ponderosa* (N. M.). While other species germinated in the dry soil their germination per cents. were very small. Among the intermediate species, as far as soil moisture goes, are *Abies concolor, grandis*, and *lasiocarpa, Pinus contorta, Pinus ponderosa* (Mon.), and *Pseudotsuga taxifolia* (Mon.). It is interesting to see that with one exception the only species that germinated in the dry culture were either *Pinus ponderosa* or *Pseudotsuga taxifolia.* The former from the Black hills, New Mexico, and Southern Idaho and the latter from New Mexico, Colorado, and Idaho. The line is evidently drawn between Southern Idaho and Montana as to whether these species will germinate in the dry culture or not, since both species from Montana did not germinate in the dry culture. Another interesting fact is that there are no moisture-loving species in the Rocky Mountains so far as this classification and these species are concerned, since there are no species that germinated only in the wet soil.

On page 46 are given the curves of *Pinus ponderosa* and *Pseudotsuga taxifolia* in their relation to soil moisture. These curves show that germination is delayed, the curve rises less rapidly, the period is shorter, and the final per cent. lower with a decrease in soil moisture.

TABLE VI

THE EFFECT OF *Soil Moisture* ON GERMINATION

Pacific Coast Species

Species	Dry Soil			Medium Wet Soil			Wet Soil		
	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus ponderosa (Calif.)	—	—	—	68	12	6.0	42	67	61.0
Pinus jeffreyi	—	—	—	80	6	12.0	31	77	22.0
Pinus lambertiana	—	—	—	—	—	—	70	36	2.5
Pinus coulteri	—	—	—	90	8	3.0	52	41	15.5
Abies magnifica	—	—	—	—	—	—	44	52	18.0
Libocedrus decurrens	20	1	0.5	—	—	—	29	73	6.0
Sequoia washingtoniana	—	—	—	—	—	—	16	18	7.0
Tsuga heterophylla	—	—	—	—	—	—	66	01	0.5
Picea sitkensis	—	—	—	—	—	—	22	60	22.5
Larix occidentalis	—	—	—	—	—	—	—	—	—
Pseudotsuga taxifolia	—	—	—	—	—	—	22	28	6.0

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CLASSIFICATION OF SPECIES BASED UPON THE EFFECT OF *Soil Moisture* UPON GERMINATION

Eastern Hardwoods

Xerophilous Species	Xero-mesophilous Species	Mesophilous Species
Robinia pseudacacia	*Catalpa speciosa* (Neb.)	*Catalpa speciosa* (Ind.)
Acer rubrum		*Quercus rubra*
		Betula papyrifera

Eastern Conifers

Pinus divaricata		
Pinus divaricata (F. S.)	*Pinus palustris*	
	Abies balsamea	
Pinus resinosa	*Pinus strobus*	*Pinus taeda*

Rocky Mountain Species

Pinus ponderosa (S. D.)	*Abies concolor*	
Pinus ponderosa (N. M.)	*Abies grandis*	
Pinus ponderosa (H.)	*Abies lasiocarpa*	
Pinus ponderosa (Id.)	*Pinus contorta*	
Pseudotsuga taxifolia (N. M.)	*Pseudotsuga taxifolia*	
Pseudotsuga taxifolia (Id.)	(Mon.)	
Pseudotsuga taxifolia (Colo.)	*Pinus ponderosa*	
Pinus monticola	(Mon.)	

Pacific Coast Species

Libocedrus decurrens	*Pinus ponderosa* (Calif.)	*Tsuga heterophylla*
	Pinus jeffreyi	*Picea sitkensis*
	Pinus coulteri	*Pseudotsuga taxifolia* (Wash.)
		Pinus lambertiana
		Abies magnifica
		Sequoia washingtoniana

In Table VI in every case where conclusions were possible it was noted that the beginning of germination was delayed and the germination period was shortened with the decrease of soil moisture. In every case the germination per cent. was highest in the wet soil culture.

For some unaccountable reason *Libocedrus decurrens* germinated in the very dry and wet cultures but not in the medium wet one. However, the four drought resistant species stand out

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conspicuously: *Pinus ponderosa, Pinus jeffreyi, Pinus coulteri,* and *Libocedrus decurrens.* This table shows that the Pacific coast species are predominantly moisture-loving.

The foregoing table is a classification of all species used in the soil moisture experiments upon the basis of whether they germinated in all three soil moisture cultures, in two of them or in only one of them. These three groups are called by the terms xerophilous, xero-mesophilous, and mesophilous. Xerophilous species are those that germinated in all three cultures; xero-mesophilous species are those that germinated in the medium wet and the wet soil cultures; and mesophilous species are those that germinated only in the wet soil culture.

TABLE VII

THE EFFECT OF *Soil Texture* ON GERMINATION

Eastern Species

Species	Loam			Sand			Gravel		
	Began. Days	Period. Days	Final. Per Cent	Began. Days	Period. Days	Final. Per Cent	Began. Days	Period. Days	Final. Per Cent
Pinus strobus	22	50	10.7	18	34	11.0	34	38	7.0
Pinus divaricata	12	32	54.5	12	38	72.0	10	40	45.5
Pinus divaricata (F. S.)	14	20	39.5	16	18	32.5	16	18	28.0
Pinus resinosa	24	16	30.5	20	54	85.0	16	8	16.5
Pinus palustris	31	53	10.5	26	54	12.5	22	62	9.5
Pinus taeda	34	6	19.0	28	12	41.0	40	1	1.0
Abies balsamea	18	30	11.0	14	34	18.5	16	40	7.0
Catalpa speciosa	18	1	1.0	0	0	0.0	0	0	0.0
Catalpa speciosa (Neb.)	16	12	91.0	16	12	92.0	16	1	9.0
Quercus rubra	40	28	28.0	38	46	24.0	30	54	16.0
Robinia pseudacacia	8	16	28.8	8	18	39.5	8	18	11.5
Betula papyrifera	34	1	1.0	34	1	3.0	34	1	0.5
Acer rubrum	18	30	17.0	24	18	13.0	18	8	8.0
Gleditschia triacanthos	0	0	0.0	34	1	1.0	0	0	0.0

Tables VII, VIII, and IX show the effect of soil texture upon the same species.

Table VII shows that for the 12 species considered in the final results only one germinated first in the loam culture. Three germinated simultaneously in all cultures, three first in the sand, and four germinated first in the gravel. Three species had the longest germination period in loam, two in sand and 5 in gravel.

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THE EFFECT OF *Soil Texture* UPON GERMINATION

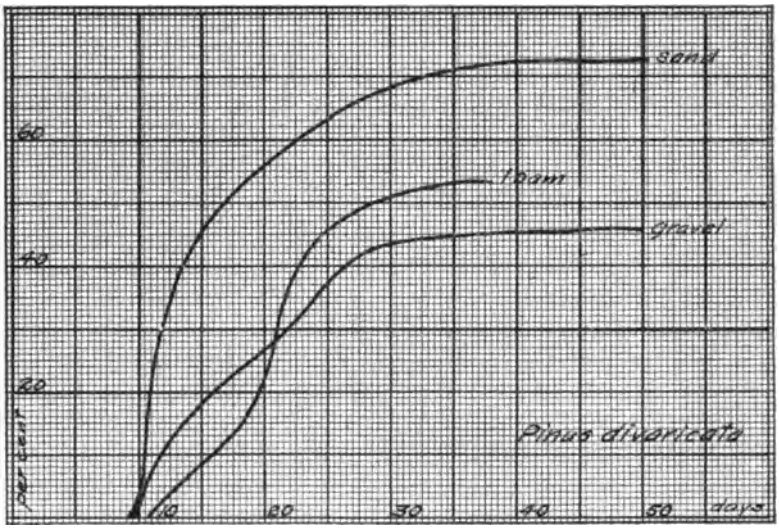

FIG. 1. The germination curves of *Pinus divaricata*.

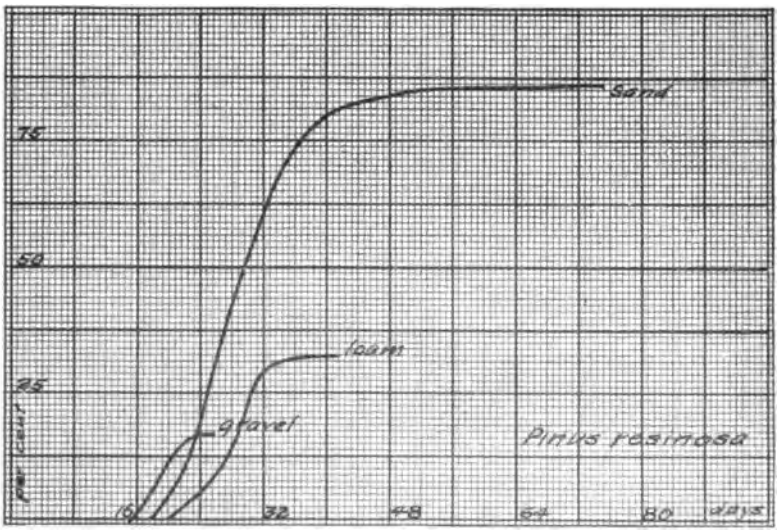

FIG. 2. The germination curves of *Pinus resinosa*.

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The two species that stand out as having the greatest germination per cent. in the loam are *Quercus rubra* and *Acer rubrum.* Nine species reached their highest germination per cents. in the sand and in this group the following stand out most conspicuously: *Pinus divaricata, Pinus resinosa, Pinus palustris, Pinus taeda,* and *Robinia pseudacacia.* Being species of sandy habitats it is quite easy to see why they should germinate better in the sand. In the gravel, which is a poor moisture retainer, it is interesting to compare such a drought enduring species like *Pinus divaricata* and such a moisture-loving species like *Pinus taeda.*

On page 50 are given the curves for *Pinus divaricata* and *Pinus resinosa.*

TABLE VIII

THE EFFECT OF *Soil Texture* ON GERMINATION

Rocky Mountain Species

Species	State	Loam			Sand			Gravel		
		Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent	Began, Days	Period, Days	Final, Per Cent
Pinus ponderosa	S.D.	10	32	58.0	8	20	57.5	8	38	44.0
Pinus ponderosa	Harney	14	14	52.0	14	26	45.0	14	8	13.0
Pinus ponderosa	N.M.	14	40	56.0	10	26	71.5	12	12	57.5
Pseudotsuga taxifolia	N.M.	12	26	63.0	10	22	70.5	10	14	63.5
Pseudotsuga taxifolia	Colo.	12	42	91.0	10	38	83.5	10	44	80.0
Abies concolor	Colo.	24	50	38.0	18	66	51.0	20	48	34.0
Pinus contorta	Colo.	14	80	22.0	20	66	19.5	16	70	40.5
Pinus ponderosa	Mon.	18	12	10.0	18	48	11.0	18	1	4.0
Pseudotsuga taxifolia	Mon.	14	34	20.5	12	44	43.0	12	42	44.5
Pseudotsuga taxifolia	Idaho	18	30	20.5	20	54	11.0	16	70	43.0
Pinus ponderosa	Idaho	36	52	43.0	44	52	59.0	20	78	71.0
Abies grandis	Idaho	36	36	4.0	46	6	2.0	36	36	3.0
Abies lasiocarpa	Idaho	30	30	6.0	0	0	0	0	0	0
Pinus monticola	Idaho	24	50	22.5	24	50	11.5	24	50	13.5

Table VIII gives the results for the Rocky Mountain species. Out of 13 species, 8 germinated first in sand or in gravel, only one germinated first in loam, and four germinated simultaneously in loam and in sand or gravel. Eight species show a longer period of germination in sand or gravel than in loam, and 5 species show the same length of period in either sand or gravel and in loam. Six species show a higher germination per cent. in

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THE EFFECT OF *Soil Texture* UPON GERMINATION

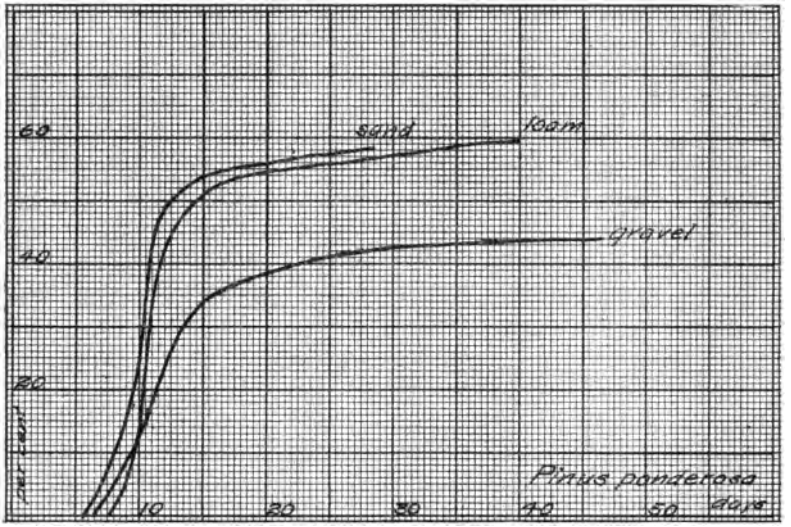

FIG. 1. The germination curves of *Pinus ponderosa* (S. D.).

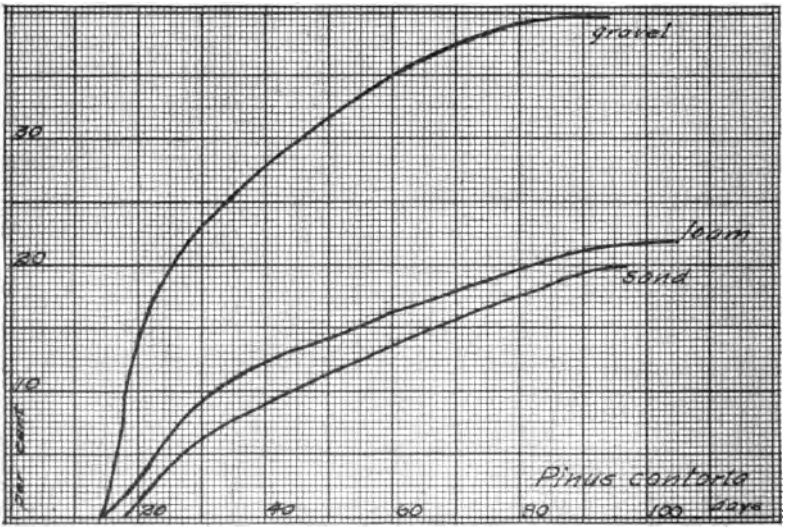

FIG. 2. The germination curves of *Pinus contorta*.

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THE EFFECT OF *Soil Texture* UPON GERMINATION

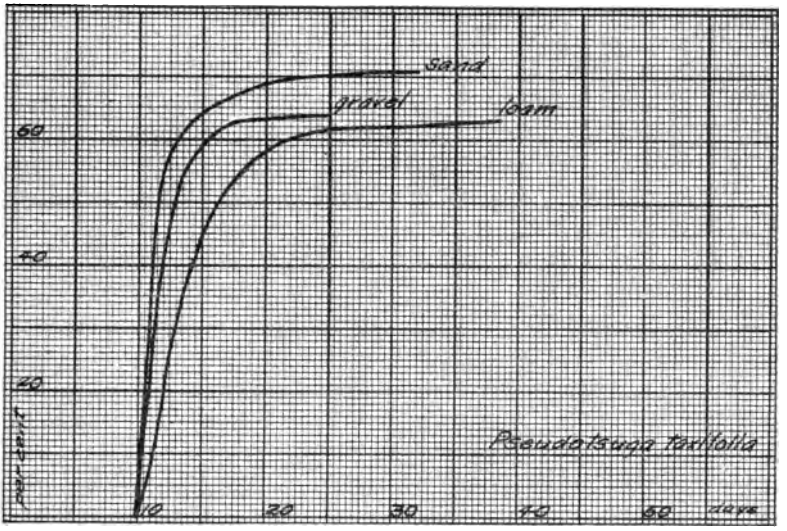

FIG. 1. The germination curves of *Pseudotsuga taxifolia* (N. M.).

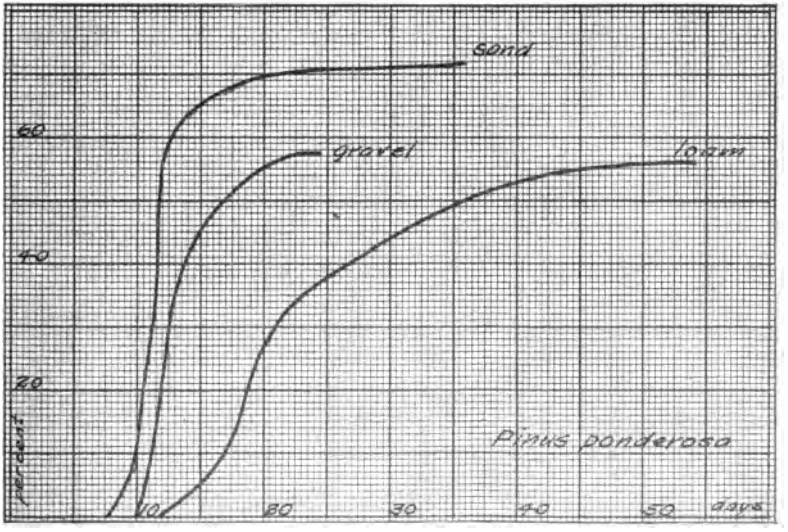

FIG. 2. The germination curves of *Pinus ponderosa* (N. M.).

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THE EFFECT OF *Soil Texture* UPON GERMINATION

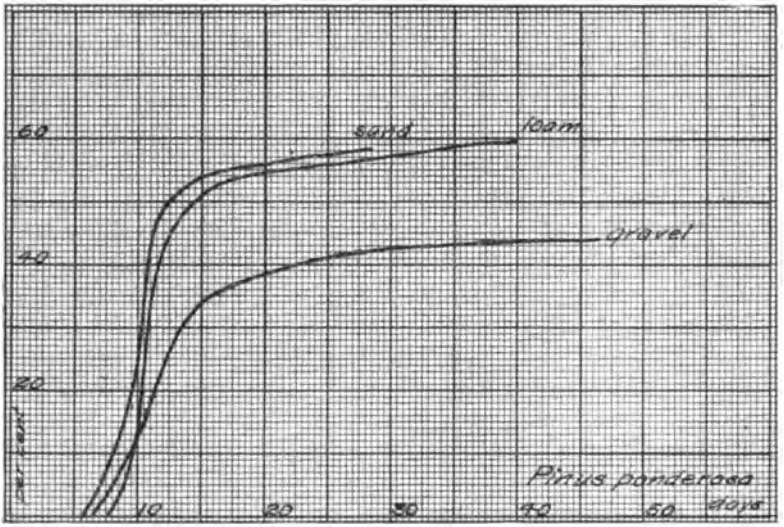

FIG. 1. The germination curves of *Pinus ponderosa* (S. D.).

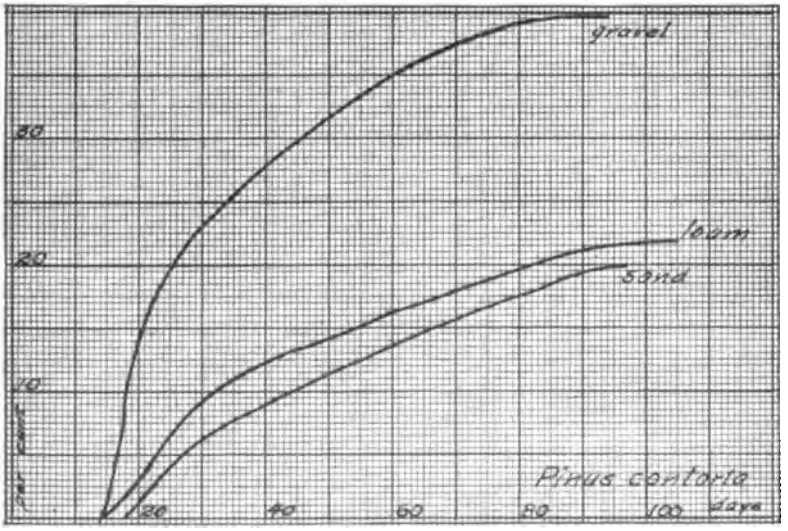

FIG. 2. The germination curves of *Pinus contorta*.

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THE EFFECT OF *Soil Texture* UPON GERMINATION

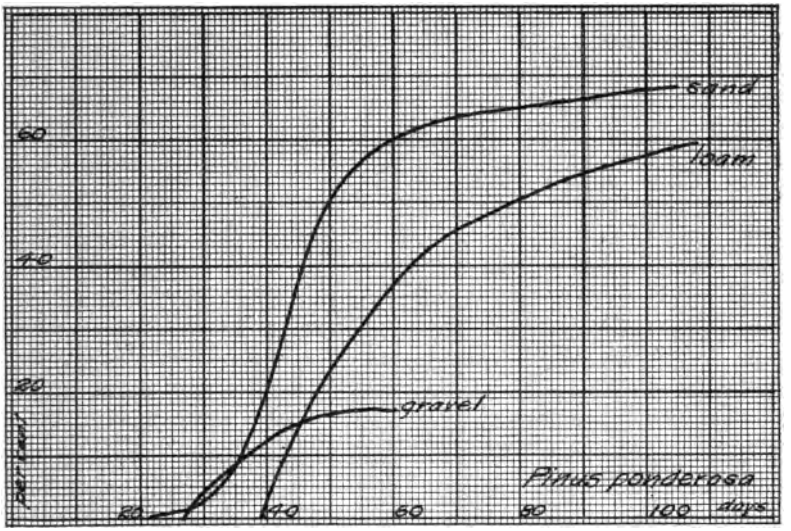

FIG. 1. The germination curves of *Pinus ponderosa* (Calif.).

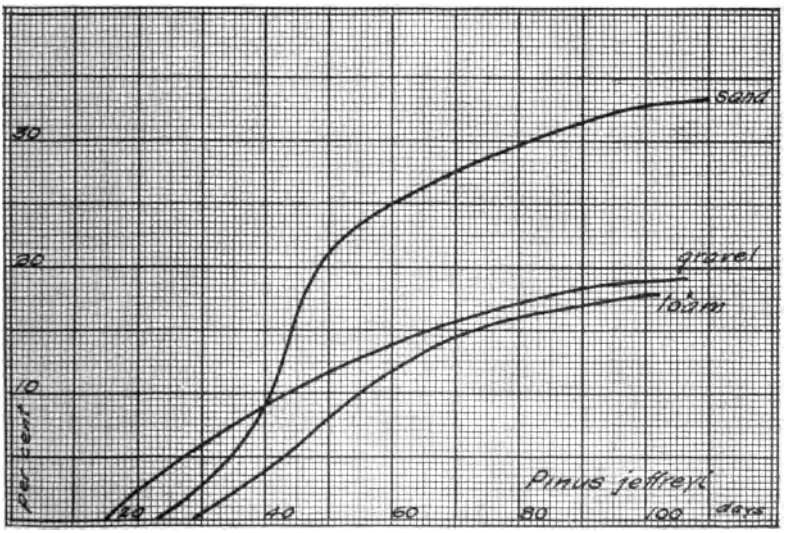

FIG. 2. The germination curves of *Pinus jeffreyi.*

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Tables X, XI, and XII give the results of the effect of light, soil moisture, and soil texture upon certain groups of species as they were classified on page 48. While the foregoing tables group the species and the final results on the basis of the geographical distribution of the species, these tables divide all species into three groups based upon the amount of soil moisture necessary for germination. The tabulation of the final data on this basis is probably more significant than any other that could be offered.

The data for the xerophilous species are given in Table X. The average figures given at the bottom of the table show that germination begins first in the dense shade, next in the medium shade, and last in the light; that the germination period is longest in the dense shade; that germination begins last in the dry soil; that the germination period is shortest in the dry soil; that germination begins first in the gravel and that the shortest germination period is in the loam and gravel. Of the 14 species given in this table, 13 germinated in the dense shade before they did in the open, 9 showed longer germination periods in the dense shade than in the open light, 12 germinated in wet soil before they did in dry soil, 13 had shorter germination periods in the dry soil than in the wet, and 9 germinated in gravel before they did in loam.

Table XI gives the results for the xero-mesophilous species. The average figures given in this table show that germination begins first in dense shade, next in medium shade, and last in open light; that the germination periods are longest in the medium and dense shade; that germination begins last in the medium dry soil; that the germination period is shortest in the medium dry soil; that germination begins first in the sand or in the gravel; and that the germination period is shortest in the gravel. Out of 13 species listed in this table 9 germinated in dense shade before they did in the open, 7 showed longer germination periods in the dense shade than in the open light, 12 germinated in the wet soil before they did in the medium dry soil, 12 showed shorter germination periods in the dry soil and 9 out of 11 germinated first in either sand or gravel.

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The data for the mesophilous species are given in Table XII. The average figures at the bottom of the table show that germination began in dense shade, followed by medium shade and open light; that the germination period is longest in the case of the dense shade; that germination began first in the loam and last in the gravel; and that the germination period was shortest in loam. Out of the 10 species listed in this table 7 germinated in the dense shade before they did in the open light, 4 out of 8 species showed longer germination period in the dense shade than in the open light; and 7 showed shorter germination periods in the loam and sand than in the gravel.

These three groups show exactly the same results so far as light and soil moisture go. From the standpoint of soil texture there are some interesting results. In the xerophilous species germination usually begins in the gravel, in the xero-mesophilous species it usually begins in the sand; and in the mesophilous species it usually begins in the loam, as the average figures and number of species in each case testify. In the xerophilous species the germination period is shortest in the loam and gravel, in the xero-mesophilous it is shortest in the gravel, and in the mesophilous species the period is shortest in the loam. That xerophilous species germinate sooner in the sand and gravel than in the loam is due undoubtedly to the amount of oxygen in these soils. This suggests that oxygen is more necessary for the germination of xerophilous species than is the case in mesophilous ones. In the mesophilous species germination begins sooner in the loam indicating that soil moisture is more necessary to them than oxygen. In the case of the light and the soil moisture experiments it has been shown that favorable moisture conditions lengthen the time of germination. In these cases it was found that the shortest periods were in the open light and in the dry soil. This same theory is proven in the case of the soil texture experiments. It is well known that loam is favorable for germination on account of its moisture-retaining properties and that gravel is favorable on account of its great amount of aeration. Sand is intermediate between these and combines enough of the soil moisture property of the loam with the aeration of the gravel

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TABLE X

THE EFFECT OF *Light, Soil Moisture,* AND *Soil Texture* ON THE GERMINATION OF *Xerophilous* SPECIES

Species	Light						Soil Moisture						Soil Texture			
	Check Culture		Medium Shade		Dense Shade		Dry Soil		Medium Wet Soil		Check Culture		Sand		Gravel	
	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days
Pinus divaricata	12	32	10	26	10	38	40	24	14	50	12	32	12	38	10	40
Pinus divaricata (F. S.)	14	20	14	26	10	24	28	12	22	18	14	20	16	18	16	18
Pinus resinosa	24	16	16	24	14	14	68	1	24	40	24	16	20	54	16	8
Acer rubrum	18	30	16	34	14	34	24	1	24	26	18	30	24	18	18	8
Robinia pseudacacia	8	16	6	18	6	18	10	30	8	32	8	16	8	18	8	18
Pinus ponderosa (S. D.)	10	32	10	22	10	34	26	26	12	36	10	32	8	20	8	38
Pinus ponderosa (Harney)	14	14	8	26	8	26	34	6	22	18	14	14	14	26	14	8
Pinus ponderosa (N. M.)	14	40	12	32	10	12	22	18	20	16	14	40	10	26	12	12
Pseudotsuga taxifolia (N. M.)	12	26	10	12	10	16	12	6	12	44	12	26	10	22	10	14
Pinus ponderosa (Id.)	36	52	24	66	14	82	90	8	14	72	36	52	44	52	20	78
Pseudotsuga taxifolia (Id.)	18	30	16	64	10	64	24	1	20	32	18	30	20	54	16	70
Pseudotsuga taxifolia (Colo.)	12	42	12	36	8	36	14	24	12	42	12	42	10	38	10	44
Pinus monticola (Id.)	24	50	16	58	14	60	48	1	18	38	24	50	24	50	24	50
Libocedrus decurrens	29	73	24	18	16	52	20	1	0	0	29	73	28	58	28	68
Averages	17.5	33.7	13.8	33.0	11.0	36.4	33.0	11.4	17.0	36.0	17.5	33.8	17.7	35.0	15.0	33.8

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TABLE XI

THE EFFECT OF *Light, Soil Moisture,* AND *Soil Texture* ON THE GERMINATION OF *Xero-mesophilous* SPECIES

Species	Light						Soil Moisture				Soil Texture			
	Check Culture		Medium Shade		Dense Shade		Medium Wet Soil		Check Culture		Sand		Gravel	
	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days
Pinus strobus	22	50	16	54	14	26	30	34	22	50	18	34	34	38
Pinus palustris	31	53	32	82	32	62	36	50	31	53	26	54	22	62
Abies balsamea	18	30	18	38	18	36	22	22	18	30	14	34	16	40
Catalpa speciosa (Neb.)	16	12	14	20	14	14	22	6	16	12	16	12	16	1
Abies concolor	24	50	18	54	14	60	80	26	24	50	18	66	20	48
Pinus contorta	14	80	16	70	14	72	20	66	14	80	20	66	16	70
Pseudotsuga taxifolia (Mon.)	14	34	12	32	12	44	18	26	14	34	12	44	12	42
Pinus ponderosa (Mon.)	18	12	18	54	10	8	18	58	18	12	18	48	18	1
Abies grandis	36	36	22	62	22	60	66	10	36	36	46	6	36	36
Abies lasiocarpa	30	30	26	50	22	28	84	1	30	30	—	—	—	—
Pinus ponderosa (Calif.)	42	67	22	92	22	62	68	12	42	67	20	82	30	30
Pinus jeffreyi	31	77	22	84	20	54	80	6	31	77	26	80	20	86
Pinus coulteri	52	41	54	30	52	62	90	8	52	41	—	—	—	—
Averages	26.7	44.0	22.3	55.5	20.4	45.2	48.8	25.0	26.7	44.0	21.3	48.0	21.8	41.3

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so as to make it an ideal soil for germination. Hence we might expect to find the longest germination periods in the sand. The average figures show that this is the case in each group of species. The shortest periods in every case are either in the loam or the gravel because loam is unfavorable from one standpoint and gravel from another.

In comparing the check cultures of the three groups of species it will be seen that xerophilous species germinate first, xero-mesophilous next, and mesophilous last. In other words the drier the habitat the sooner germination starts, granting that the conditions are favorable.

TABLE XII

THE EFFECT OF *Light* AND *Soil Texture* ON THE GERMINATION OF *Mesophilous* SPECIES

Species	Light						Soil Texture					
	Check Culture		Medium Shade		Dense Shade		Check Culture		Sand		Gravel	
	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days	Began, Days	Period, Days
Pinus taeda	34	6	34	6	32	8	34	6	28	12	40	1
Catalpa speciosa (Ind.)	18	1	0	0	16	1	18	1	0	0	0	0
Quercus rubra	40	28	30	18	26	42	40	28	38	46	30	54
Betula papyrifera	34	1	34	1	34	1	34	1	34	1	34	1
Pinus lambertiana	70	36	76	20	70	24	70	36	52	16	80	18
Abies magnifica	44	52	24	54	36	54	44	52	96	2	50	48
Sequoia washingtoniana	16	18	16	6	14	14	16	18	16	24	22	1
Tsuga heterophylla	66	1	0	0	0	0	66	1	44	42	56	8
Picea sitkensis	22	60	18	64	14	36	22	60	18	64	18	64
Pseudotsuga taxifolia (Wash.)	22	28	22	54	14	62	22	28	38	44	36	48
Averages[2]	35.9	28.6	31.7	27.9	30.0	30.1	38.7	25.5	40.4	27.9	40.7	27.0

Tables similar to X, XI, and XII were constructed showing the effect of these habitat factors upon the germination per cent. of the species. This table is not given but the most significant facts which it shows are given here and in a later table. It is interesting to note that of the 37 species used in the experiments the highest

[2] *Catalpa speciosa* and *Tsuga heterophylla* not included in averages of light cultures. *Catalpa speciosa* not included in soil-texture averages.

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germination per cent. did not always occur under the influence of the same conditions. Considering all factors and all degrees of these factors the highest germination per cents. occurred as follows:

In open light	3
In medium shade	7
In dense shade	11
In sand	12
In gravel	4
Total	37

The distribution of these species in the three groups as determined by soil moisture is not significant. The only interesting fact to be found is that no mesophilous species germinated highest in the gravel.

TABLE XIII

SUMMARY OF THE *Beginning of Germination* BY NUMBER OF SPECIES

Light

Germinated First in	Number of Species			Total
	Xerophilous	Xero-meso-philous	Mesophilous	
Open light	0.33	2.33	0.50	3.17
Medium shade	2.33	2.33	1.00	5.67
Dense shade	11.34	8.33	5.50	25.16
Total	14.00	13.00	7.00	34.00
Soil Moisture				
Dry soil	1.33	....	....	1.33
Medium wet soil	3.83	0.50	....	4.33
Wet soil	8.83	12.50	....	21.34
Total	14.00	13.00	....	27.00
Soil Texture				
Loam	2.50	2.17	2.50	7.17
Sand	4.00	5.17	3.00	12.17
Gravel	7.50	3.66	1.50	12.66
Total	14.00	11.00	7.00	32.00

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Tables XIII, XIV, and XV take the same data as presented in previous tables but the results are given by number of species rather than by average numbers. The number of species in each group which performed certain things under certain conditions are given without respect to the name of the species. This is perhaps a better way of drawing conclusions than to use average figures. Each species is counted in its proper column; if a species, for example, germinated simultaneously in two cultures it counted one half in each column.

TABLE XIV

SUMMARY OF THE *Length of the Germination Period* BY NUMBER OF SPECIES

Light

Shortest Germination Period in	Number of Species			Total
	Xerophilous	Xeromeso-philous	Mesophilous	
Open light	7.00	5.00	2.50	14.50
Medium shade	4.50	3.00	3.50	11.00
Dense shade	2.50	5.00	1.00	8.50
Total	14.00	13.00	7.00	34.00
Soil Moisture				
Dry soil	12.00	....	....	12.00
Medium dry soil	1.00	12.00	....	13.00
Wet soil	1.00	1.00	....	2.00
Total	14.00	13.00	....	27.00
Soil Texture				
Loam	3.83	4.00	3.00	10.83
Sand	4.33	3.00	2.00	9.33
Gravel	5.83	4.00	2.00	11.83
Total	14.00	11.00	7.00	32.00

Out of 34 species 31 germinated first in either of the two shade cultures and only 3 began their germination in the open light. The tendency to germinate first in the shade is more marked in the case of the xerophilous and the mesophilous species and less marked in the xero-mesophilous. Out of 27 species,

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over 21 germinated first in the wet soil. In both the xerophilous and the xero-mesophilous species the tendency is to germinate first in the wet soil. In the experiments on soil texture the tendency is for the xerophilous species to germinate first in the gravel and sand, for the xero-mesophilous to germinate first in the sand, and for the mesophilous species to germinate first in the sand and loam. This is a most interesting result, in view of the moisture and air conditions in these soils. On the whole the tendency is for most of the species to begin germinating in the sand and gravel; about 25 out of 32 species began germinating in either of these two kinds of soils. In the soil texture data it is interesting to compare the germination of xerophilous and mesophilous species in the gravel. Such a comparison shows 7.50 xerophilous species germinated first in the gravel and only 1.50 mesophilous species.

From Table XIV it is apparent that out of 34 species 14.5 showed the shortest germination period in open light and that the number of species of this kind decreases as the intensity of the light decreases. In other words shade increases the length of the germination period. In the soil moisture experiments the shortest periods were in 25 species out of 27 found in the dry or the medium wet soil. In the soil texture experiment the species are very evenly distributed. Loam and gravel, the two extreme soils from the standpoint of soil moisture and soil aeration, show the greatest number of species and the sand culture shows the least. This fact is in harmony with the idea that favorable conditions, such as we found in the light and the soil moisture experiments, lengthen the period of germination.

Table XV shows that out of 14 drought-enduring species 12 reached their greatest germination per cent. in the shade; out of 13 xero-mesophilous species 10 reached their highest per cent. in the shade; and out of 8 mesophilous species 7 reached their highest per cent. in the shade cultures. Out of a total of 35 species, 29 germinated highest in the shade cultures. Out of 27 species tried in the soil moisture experiments 23 germinated highest in the wet soil and 4 highest in the medium soil. None reached their highest per cent. in the dry soil cultures. Among

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the xerophilous species the highest per cents. are in the loam and sand, among the xero-mesophilous species the highest per cents. are in the sand while in the mesophilous species the highest per cents. are in the sand and loam. Out of 34 species, 18.5 germinated highest in the sand, thus showing the value of this class of soil for seed germination.

TABLE XV

SUMMARY OF THE *Final Germination Per Cent.* BY NUMBER OF SPECIES.

Light

Greatest Germination Per Cent in	Number of Species			Total
	Xerophilous	Xeromeso-philous	Mesophilous	
Open light	2.00	3.00	1.00	6.00
Medium shade	3.00	7.00	2.50	12.50
Dense shade	9.00	3.00	4.50	16.50
Total	14.00	13.00	8.00	35.00
Soil Moisture				
Dry soil	0.00	....	....	0.00
Medium wet soil	3.00	1.00	....	4.00
Wet soil	11.00	12.00	....	23.00
Total	14.00	13.00	....	27.00
Soil Texture				
Loam	6.00	1.00	2.50	9.50
Sand	5.00	8.00	5.50	18.50
Gravel	3.00	2.00	1.00	6.00
Total	14.00	11.00	9.00	34.00

THE EFFECT OF HABITAT FACTORS UPON STEM AND ROOT DEVELOPMENT

Following the experiments upon germination, some of the species were grown for several months for the purpose of obtaining root and stem measurements. Since damping-off reduced materially the number of seedlings as time went on, the number of plants upon which final measurements could be taken was naturally reduced. Hence the results are not based upon as many measurements as was originally intended.

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The species retained for this work were *Pinus ponderosa* (S. D.), *Robinia pseudacacia, Quercus rubra,* and *Pinus strobus.* Stem and root measurements were taken upon the first three of these species and stem measurements only upon the last one. Each measurement represents the average of 10 representative plants, except in case of *Quercus rubra* where from 3 to 14 plants were used depending upon the number available. The measurements of the stems of *Pinus ponderosa* and *Robinia pseudacacia* were taken at two different ages, namely at the age of two and three months, but the plants used at the age of three months were not the same ones used at the end of two months. Hence in the data the three months' old plants are not necessarily larger than the two months' old plants, although they usually are. Root measurements of *Pinus ponderosa* and *Robinia pseudacacia* were taken at the end of three months. Both stem and root measurements for *Quercus rubra* were taken at the age of five months.

The effect of light on stem and root development is shown in the following table:

THE EFFECT OF *Light* ON STEM AND ROOT DEVELOPMENT

Conifers

Degrees	Stem Measurements			Root Measurements	
	P. ponderosa		*P. strobus*	*P. ponderosa* (3 Mos.)	
	2 Mos., Cm.	3 Mos., Cm.	2 Mos., Cm.	Tap, Cm.	Laterals, Cm.
Open light	2.76	2.59	4.31	5.93	1.11
Medium shade	2.90	3.13	5.50	5.80	.62
Dense shade	3.50	...	6.35	...	...

Hardwoods

Degrees	Stem Measurements			Root Measurements (Tap)	
	R. pseudacacia		*Q. rubra*	*Rob. pseud.*	*Q. rubra*
	2 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.
Open light	6.00	7.02	9.40	9.64	13.8
Medium shade	5.80	5.95	7.30	7.16	10.2
Dense shade	5.00	5.52	8.00	5.69	10.2

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From these tables it will be seen that *Pinus ponderosa* increases its length of stem with a decrease in light intensity both at the age of two and at three months. This is likewise true for *Pinus strobus*. For *Robinia pseudacacia*, however, both at the age of two and three months, there is a striking decrease in stem height with a decrease in light intensity. *Quercus rubra* behaves the same way, except that the length of stem is greater in the medium shade than in the dense shade. This development is shown very well by the accompanying photographs.

In the case of all species it is strikingly shown that the length of the tap root and the total length of the laterals decrease with decrease in light intensity.

In so far as the stem and its relation to light is concerned it is quite evident that hardwoods behave differently from conifers. As has been pointed out conifers tend to increase their height growth with decrease in light intensity while hardwoods tend to decrease this growth with decrease in light intensity. Evidently conifers can adapt themselves to these unfavorable light conditions better than hardwoods. In the hardwoods the reciprocal relation of roots and stem in their dependence upon light is strikingly shown.

THE EFFECT OF *Soil Depth* UPON STEM AND ROOT DEVELOPMENT

Conifers

Degrees Soil Depth	Stem Measurements			Root Measurements	
	Pinus pond.		*P. strobus*	*P. ponderosa* (3 Mos.)	
	2 Mos., Cm.	3 Mos., Cm.	2 Mos., Cm.	Tap, Cm.	Laterals, Cm.
Deep	2.85	2.69	4.35	9.51	.47
Medium	2.76	2.59	4.31	5.93	1.11
Shallow	2.60	2.68	4.25	3.97	4.61

Hardwoods

Degrees Soil Depth	Stem Measurements			Root Measurements (Tap)	
	R. pseudacacia		*Q. rubra*	*Rob. pseud.*	*Q. rubra*
	2 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.
Deep	6.45	7.20	6.50	15.55	20.4
Medium	6.00	7.02	9.40	9.64	13.8
Shallow	5.70	6.04	5.90	3.30	6.9

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The foregoing tables show the effect of soil depth upon root and stem development for the same species and ages of stock.

In the case of stem development in all species except *Quercus rubra,* the height of the stem increases with increase in soil depth. The increase in length between the deep soil and the shallow soil is not very great, *i. e.,* in the pines it is never over 0.25 cm. and in *Robinia* it is never over 1.16 cm. In *Quercus rubra* the smallest height growth is in the shallow soil but the greatest height growth is in the medium deep soil. It is interesting to note that in all cases the greatest total length of stem and root together is in the plants grown in deep soil.

As is to be expected the length of the tap root is materially decreased as the soil depth decreases. In *Pinus ponderosa* the tap root is 2½ times longer, in *Robinia* it is 5 times longer and in *Quercus* it is 3 times longer in the case of the deep soil than in the shallow soil. The length of lateral roots was taken only in the case of *Pinus ponderosa* and this species is representative of what took place in all the other species. In this species the total length of lateral roots increased with decrease in soil depth. In the case of *Robinia* this is strikingly shown in the photographs. This indicates that whether a tree has deep-seated roots or superficial roots depends largely upon the depth of the soil in which the tree grows. The terms "deep-rooted species" and "shallow-rooted species" have therefore only limited significance and the real basis for these terms is in most cases the environment.

In the following table are given the data upon the effect of soil moisture upon root and stem development:

THE EFFECT OF *Soil Moisture* UPON STEM AND ROOT DEVELOPMENT
Conifers and Hardwoods

Degrees	Stem Measurements					Root Measurements[3]		
	Pinus ponderosa		*Robinia pseud.*		*P. strobus*	*P. pond.*		*R. pseud.*
	2 Mos., Cm.	3 Mos., Cm.	2 Mos., Cm.	3 Mos., Cm.	2 Mos., Cm.	Tap, Cm.	Lat., Cm.	Tap, Cm.
Dry	..	..	2.60	..	..	..	..	6.00[4]
Medium	1.80	2.02	4.35	3.80	3.90	7.33	2.65	7.54
Wet	2.76	2.59	6.00	7.02	4.31	5.93	1.11	9.64

[3] Age, 3 months.
[4] Age, 2 months.

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In connection with the soil moisture experiments a very interesting fact was noted. Both *Pinus ponderosa* and *Robinia pseudacacia* wilted on January 1, just exactly two months after the seeds were sown. The soil moisture at the time was determined to be 6.6 per cent. It happens that at three different times the moisture content was far below this figure. On October 28 the seeds were sown, on November 7 the moisture content was 4 per cent., on the 11th it was 4.6 per cent. and again on December 5 it fell to 6.1 per cent. *Robinia pseudacacia* germinated first on November 9 and the *Pinus ponderosa* on November 26. It is evident from this occurrence that more moisture is needed for the early development of the seedlings than is necessary for germination. On the 9th of January this fact was further emphasized. While taking root and stem measurements and digging up the seedlings two germinating seeds of *Robinia* were found. The moisture samples taken on this day show 5.7 per cent. moisture in the dry culture. As a result of this condition no stem and root measurements appear in the dry column at the age of three months.

In all species measured the length of the stem decreases with diminishing moisture supply and the fact is noted that this decrease is greater in the case of *Robinia* than it is in the case of *Pinus ponderosa* or *Pinus strobus*. This indicates the greater drought resistance of the conifers as compared to the hardwoods.

In the case of the root development of *Pinus ponderosa* it is shown that both the tap root and the total length of lateral roots increase with diminishing moisture supply. For *Robinia* the result was quite different, for it was found that the length of the tap root decreases with diminishing moisture. While *Pinus ponderosa* seems to be able to develop roots to reach the lower moisture layers of soil, *Robinia* is unable to do this.

The following table gives the results on the effect of soil texture upon the development of the stem and roots of these species.

The greatest length of stem in *Pinus ponderosa* was found to be in the case of the two-months-old seedlings in the loam and the next greatest length in the gravel. In the case of the three-months-old trees the greatest length was in the gravel and the

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next greatest in the loam. In the case of *Pinus ponderosa* clearly the greatest length is either in the loam or in the gravel and the shortest length of stem is in the sand. Loam and gravel are, as we have seen, quite opposite when it comes to moisture retentiveness, hence the good development of plants grown in gravel must be attributed to other properties of gravel, namely, the amount

THE EFFECT OF *Soil Texture* UPON STEM AND ROOT DEVELOPMENT

Conifers

Degrees	Stem Measurements			Root Measurements	
	P. ponderosa		*P. strobus*	*P. ponderosa* (3 Mos.)	
	2 Mos., Cm.	3 Mos., Cm.	2 Mos., Cm.	Tap, Cm.	Laterals, Cm.
Loam	2.76	2.59	4.31	5.93	1.11
Sand	2.15	2.06	4.80	6.22	.94
Gravel	2.65	2.70	4.10	7.83	4.01

Hardwoods

Degrees	Stem Measurements			Root Measurements (Tap)	
	R. pseudacacia		*Q. rubra*	*Rob. pseud.*	*Q. rubra*
	2 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.	3 Mos., Cm.	5 Mos., Cm.
Loam	6.00	7.02	9.40	9.64	13.80
Sand	4.75	4.75	5.90	10.85	15.70
Gravel	3.80	4.25	5.70	10.11	16.00

of air in the soil. *Pinus strobus* shows the greatest height growth in the sand. *Robinia* shows the greatest length of stem in the loam and the least in the gravel. This is in peculiar contrast to *Pinus ponderosa*. For growth *Robinia* is evidently more particular about soil moisture than about the amount of air in the soil. *Quercus rubra* shows the greatest height growth in the loam and the least in the gravel.

The tap root of *Pinus ponderosa* is of greatest length in the gravel and least in the loam, and the total length of lateral roots is greatest in the gravel. This naturally follows from the fact that, as has been pointed out before, gravel allows water to percolate rapidly and the top layers dry out very soon, hence the

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plant has to go deep for its moisture. In the cases of *Robinia* and *Quercus* the greatest length of laterals and the greatest length of the tap root was found in the sand or gravel, again bearing out the fact that sands and gravels are poor soils for retaining moisture.

THE RELATION OF SIZE AND WEIGHT OF SEED TO GERMINATION PER CENT. AND EARLY DEVELOPMENT

During the process of counting between 100,000 and 125,000 seeds of various kinds for these experiments the fact that seeds of the same species varied considerably in size came to the author's notice very forcibly. In his experience in the woods as well as in seed extracting it was often noted that many factors may affect the size of seeds. In general, it may be said that the size of the seeds of any one species depends upon one or more of the following factors:

1. The size of the cone.
2. The position of the seed in the cone.
3. The development of the cone.
4. The age of the tree.
5. The physiological condition of the tree.
6. The site upon which the tree grew.
7. The climatic variety of the species.

It is an old experience that large cones produce large seeds and small cones small seeds. The seeds at the extreme base and the extreme apex of the cone are very often very much smaller than in other parts of the cone. External conditions such as temperature and moisture, may affect in no small degree the seed while it is maturing, thus retarding its morphological development. It has been observed that middle-aged trees produce the largest cones and the largest seeds, while very young or very old trees usually produce small cones and small seeds. The physiological condition of the tree may affect the size of the seed. Since seed crops are dependent upon the accumulated food in the tree, it is reasonable to suppose that a paucity of such food ma-

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terial will produce smaller seeds than in cases where there is a great accumulation. It has been repeatedly shown that after a seed year the amount of accumulated food in the medullary rays and other food accumulation centers is reduced to a minimum. The site upon which the tree grew, naturally, is intimately connected with the amount of food material available for the embryo of the seed. For the same reason the climatic variety of the tree probably affects the size of the seed. At least, it is common knowledge that the California variety of *Pinus ponderosa* has seeds which may weigh from three to four times as much as those of the South Dakota variety. While most of these points remain to be proven experimentally, they have been indicated to the writer by various experiences and are put forth as interesting hypotheses awaiting experimental proof. Whatever the cause of the varying size of seeds is, it is quite evident from the amount of literature on the subject that this phenomenon has attracted considerable attention in recent years both in silviculture and agriculture.

That heavier and larger seeds furnish a better germination per cent. than light ones has been recognized for a long time by European silviculturists. The physiology of germination indicates that large seeds should succeed better, and repeated experiments by Bühler, Friedrich, Haack, Eisenmenger, and others establish this beyond much doubt. In fact forestry practice throughout Europe and especially in Prussia shows that smaller seeds produce fewer plants per hectare than larger ones in broadcast sowing. Favorable and unfavorable site and season conditions produce far less variation in the final results in cases where heavy seeds are sowed.

In 1904 Blumer (22) conducted at the seed laboratory of the United States Department of Agriculture a series of tests upon certain American species of tree seeds. *Pinus ponderosa* from the Rocky Mountains and *Pinus divaricata* showed the highest germination but *Pinus ponderosa* from Oregon germinated exceedingly slowly, a feature which also characterized *Pseudotsuga taxifolia* from the Pacific Coast. He noted great variation in the number of seeds per pound for the same species, especially

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for *Pinus ponderosa*. In the case of this species the difference was often as much as 100 per cent.; usually the difference in other species did not exceed 50 per cent. Schotte (23), of the Swedish Forest Experiment Station, has shown that the size of the seed and the size of the cones decrease with increasing age of the tree in the case of Scotch pine. The work (24) done on seeds by certain forest experiment stations in Europe in 1907 with spruce showed that seeds from large cones germinate earlier than those from small cones; that the largest cones produce the largest and heaviest seeds and hence the largest plants; and that the effect of the size of seed upon the life of the plant has been noticed only in the first two years of its growth.

In Busse's (25) experiments pine seeds were graded by means of a Kayser centrifuge into three grades according to weight. The heaviest seed made up 68 per cent. of the stock seed, the medium weight seed 27 per cent. and the light seed 5 per cent. He recommended the first grade for field sowing but said that the third grade should not be used. Sprout tests did not show any differences in germination results. Centgraf (26) examined 247 tests of pine seed as to the relation of the weight of 1,000 grains to their germination. He failed to find a relation between weight and germinative energy or germination per cent. In fact he found that the heavier seed averaged a smaller germination per cent. than the light ones. He concluded that the slower germination of big seed is probably due to a thicker seed coat of the heavier seed which determines in part its weight and which takes up water more slowly than thin coats of light seed. Some of these results do not agree with the many experiments made by foresters in Europe. These tests being made for commercial purposes cannot therefore be taken as conclusive.

While the size and weight of seed has been recognized as a factor in germination it also has been recognized as a factor in the early development of the seedling as has been indicated in a few instances above. One finds statements in regard to this relation quite common in silvicultural works but very little material to substantiate these opinions. The view held by many writers is summarized very well by Schlich in his *Manual of Forestry* (27):

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In the case of one and the same species large, heavy seed are better than light ones. The former generally possess a greater power of germination and the resulting seedlings show a greater power of resistance against injurious external influences and a more vigorous development which in many species is due to the greater quantity of reserve food materials deposited in the seed. This superiority at the first start should not be underestimated because it is recognizable long after the seedling stage has been passed. In many cases the dominant trees grow out of the seedlings which had the better start.

The relation of size and weight of seed to germination per cent. and later development has been worked out to a much greater degree of certainty in the case of agricultural and garden seeds than in the case of forest-tree seeds. These facts have already been quite firmly established in practice and already adopted as a criterion of seed values. There is no reason why weight of seed should not play as important a part in selecting forest tree seeds as well as agricultural and garden seeds in the future, as the source and germination per cent. of those seeds.

A considerable amount of work has been done by investigators upon cereals, regarding the comparative value of heavy and light seed used in planting. Most of the work has been done with wheat, oats, and barley and the preponderance of evidence is in favor of the large seed. The hypothesis upon which this work has been based was the fact that, since the weight and size of the seed determines largely the amount of food material immediately available for the plantlet at the time of germination, it is reasonable to assume that these factors might have some influence upon the life of the plant and even upon the final crop.

Early experiments by Hellriegel, Wollny, Marek, and others (28) were favorable to the view that seeds of greater size and weight generally give more vigorous plants than those smaller and lighter. Hellriegel was of the opinion that differences at maturity between the product of heavy and light seeds are intensified when the conditions are unfavorable. Hicks and Dabney (28) have made a test of the relative effects of weight upon vigor, using many kinds of seeds. In the case of radish, vetch, sweet pea, cane, Kafir corn, rye, and oats the total weight of the seedlings in each case favored the heavy seed. The differences in germination per cent. of light and heavy seed was not

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conclusive. Only in the case of the corn was there a sufficient difference to warrant a conclusion in favor of the heavy seed. From the results of these experiments it seems logical to conclude that in general more vigorous growth and consequently a better stand in the field is secured by employing only the heavier seed. The effect of the size and weight of seed on production has been with no other plant so extensively studied as in the case of the wheat. The majority of results seem to favor the view that large and heavy seed are preferable. Zavitz (28) showed that the yield in bushels per acre was in favor of the large plump seed.

Trabut (32) found in the case of tobacco seeds that it was possible to affect a separation into heavy and light sorts through the capacity of these two kinds respectively to sink and float in water. It was found that the heavy seed produced plants which were greener, more vigorous, and of larger size. The yield from plants from the heavy seed was almost double that of the yield from the light seed. Shamel (31) secured results similar to these. Careful comparative tests of the light and heavy seeds of tobacco have proved that the best developed and most vigorous plants are always produced from the large, heavy seed while the light seed produce small, irregular and undesirable plants. In an experiment with Cuban tobacco seed Shamel found the germination of heavy seeds almost perfect while less than five per cent. of the light seeds sprouted. The plants from the heavy seed grew more rapidly than those from the light seed and reached the proper size for transplanting seven to nine days earlier than the plants from the light seed.

In the case of cotton seed, comparative production tests of the value of the heavy seed over the usual farm product have been made by the U. S. Department of Agriculture (30). The yields in pounds on equal areas in South Carolina show the gain from the use of heavy seed in two different cases to be 10.9 per cent. and 8.25 per cent. respectively.

Bolley (29) selected large and small grains from the same heads of wheat and found that the large grains generally produced the largest yields. Waldron (29) found that short wheat culms, shortheads, and those with a smaller number of grains

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bear on the whole grains of a greater weight. Walls (37), working upon the size of the grain and the germ of corn, concludes that the heaviest grains do not necessarily have the best germinating qualities and that plants from the heaviest grains attain the greatest weight, other conditions being favorable. Concerning the size of the germ he finds that the germinating properties of the kernels containing different sizes of germs may be equal; that the largest, hardiest, and most vigorous plants come from the kernels with the large germs; and that the plants from the kernels with the largest germs withstand the drought best. He says in the selection of corn, in order to insure a good stand and a large yield none but the large germed kernels should be used.

Harris (33, 34, 35) working on the differential mortality with respect to seed weight of beans and peas secured similar results, though in a different way. In the case of peas about 1,000 seeds from each of ten early varieties were weighed and planted. In seven cases out of ten the total weights of the seeds which germinated was higher than the total weights of the seeds which did not germinate. Cummings (38) worked with numerous kinds of garden seeds. He quotes numerous investigators who worked on corn, oats, wheat, sugar beets, cotton, and beans and practically all the results show an increased yield through the use of large seeds. He himself worked with squash, pumpkin, lettuce, spinach, parsley, radishes, beans, garden peas, and sweet peas. Here too the results were almost without exception in favor of the large seeds. Not only were the resulting yields larger and heavier but in most cases the yield was earlier. In the case of the radishes the large seeds produced more uniform crops one week earlier than the small seeds. Sweet peas showed earlier blossoming, a larger total yield of blossoms and a larger number of blossoms of good quality. On the whole the permanent advantages accruing from large seeds are a larger and greater number of leaves, flowers and fruits.

Present Investigations

Having on hand several climatic varieties each of *Pinus ponderosa* and *Pseudotsuga taxifolia,* I was prepared to determine

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the effect of size upon germination per cent. for many varieties of the same species. This study would also bring out some interesting relations between these varieties, as for example, correlating the size and weight of the seed with the site upon which the trees grew.

The largest and the smallest seeds were separated from the stock seed and counted, weighed, planted and carefully labelled. Of each variety of *Pinus ponderosa* 500 seeds were used except in the case of the California varieties. Due to the scant supply of these only 200 seeds of each of these were used. In the case of the *Pseudotsuga taxifolia* 200 seeds of each variety were used. After germination began counts were taken every other day. The tables below give the size of the seeds, weight of 500 seeds, the number of seeds per pound, the final germination per cent., and

Size AND *Weight of Seed* IN RELATION TO GERMINATION PER CENT.

Pinus ponderosa

Source or Variety	Size	Size, Mm.	Total Weight 500 Seeds, Gm.	Seeds Per Lb.	Final Germ. Per Cent	Per Cent in Favor of Large Seeds
South Dakota.....	Small	3–5	10.065	22,530	50.6	
	Large	5–9	20.720	11,000	53.6	3.0
Harney, N. F., S. D. ..	Small	4–6	10.845	20,900	25.0	...
	Large	6–9	20.720	11,000	40.2	15.2
Bitterroot, N. F., Mon.	Small	5–8	19.050	11,900	7.6	...
	Large	8–11	30.400	7,450	8.0	0.4
Weiser, N. F., Idaho...	Small	4–7	17.100	13,250	60.0	...
	Large	7–10	29.540	7,650	84.8	24.8
Pecos, N. F., N. M. ...	Small	4–7	16.150	14,000	65.2	...
	Large	7–9	23.470	9,650	73.4	8.2
California.....	Small	7–11	35.500	6,350	63.5	...
	Large	11–14	67.000	3,385	73.5	10.0
P. jeffreyi.....	Small	7–10	26.000	8,725	8.0	...
	Large	10–14	77.600	2,900	84.0	76.0
Pseudotsuga taxifolia						
Caribou, N. F., Idaho...	Small	..	6.040	...	32.5	...
	Large	..	8.290	...	42.5	10.0
Pecos, N. F., N. M.....	Small	..	5.450	...	65.0	...
	Large	..	7.850	...	69.0	4.0
Washington	Small	..	3.780	...	16.5	
	Large	..	6.450	...	16.0	—0.5
Colorado.....	Small	..	3.750	...	79.0	...
	Large	..	6.980	...	88.0	9.0
Madison, N. F., Mon...	Small	..	3.350	...	43.5	...
	Large	..	6.630	...	50.0	6.5

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the per cent. in favor of the large seeds. In converting grams to pounds it was assumed that 453.6 grams equals one pound. The germination period for *Pinus ponderosa* was 120 days and for *Pseudotsuga taxifolia* 100 days.

From these tables it will be seen that in every variety of *Pinus ponderosa* the final germination per cent. is in favor of the large seeds. In the case of *Pseudotsuga taxifolia* every variety except one shows a final per cent. in favor of the large seeds.

It is well known that there are definite climatic differences between the Rocky Mountains and the Pacific coast. The most conspicuous proof of this is in the flora of these regions. In general the Pacific coast is inhabited by relatively mesophilous vegetation, especially near the coast, while the vegetation of the Rocky Mountains is more xerophilous in nature. Again, the Rockies themselves show marked differences in this very respect in travelling from south to north and from east to west.

Probably the best way of studying the effect of great climatic variations upon vegetation is to use polydemic species such as we are considering here. *Pinus ponderosa* and *Pseudotsuga taxifolia* are conspicuous examples of this class of species. It is well known that both these species reach a better development on the Pacific coast than in the Rocky Mountains. It is likewise well known that they reach a far better development in the northern Rockies than in the southern. As a proof of this we have but to go to volume tables of these species in the *Woodsman's Handbook* by Graves and Ziegler. In the case of *Pinus ponderosa* three tables are given, one for the Black Hills, one for Arizona, and one for California and Montana. In studying these tables it will be seen that the maximum heights and maximum diameters and the average and maximum heights for a given diameter increase steadily in going from the Black Hills to California. In the case of the Douglas fir the same thing is true in considering the volume table for Idaho and Wyoming and that for Washington and Oregon. In the order of their favorability for tree growth, as manifested by these species these regions arrange themselves in the following order, the least favorable being given first:

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Black Hills
Arizona and New Mexico
Colorado and Wyoming
Idaho and Montana
Washington, Oregon, and California.

It is a striking fact in the case of *Pinus ponderosa* that the size and weight of the seed and their manner of germination follow exactly this same order. The smallest seeds come from the Black Hills and New Mexico and the largest from California; the total weight of 500 seeds is least in the case of the Black Hills variety and greatest in the California variety, hence the number of seeds per pound is greatest in the former and smallest in the latter variety. Furthermore, germination begins sooner, the germination period is shorter and the germination curve rises more rapidly in the case of the South Dakota and New Mexico variety than in the case of the Pacific coast variety. Some of these striking relations between seeds and site are also shown by *Pseudotsuga taxifolia*. This species shows all these relations except those of weight of seed and number of seeds per pound. There seems to be no definite relation in this respect.

On page 79 the germination curves of the climatic varieties of *Pinus ponderosa* and *Pseudotsuga taxifolia* are given and they illustrate very forcibly what has been said above concerning the behavior of these curves.

In order to determine the effect of the size of the seed upon the size of the seedling shortly after germination, the seedlings were dug up very carefully as they were counted and taken to the laboratory and measured. The total length of the hypocotyl and tap root was taken in each case, the seed being excluded from the measurement. These measurements were kept separate for the small and large seeds and the results are given below:

Pinus ponderosa (Idaho)—Age, 2 Days

200 seedlings from small seeds averaged ..... 3.07 cm.
200 seedlings from large seeds averaged ..... 3.90 cm.

These 400 seedlings were classified according to their total length as follows:

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THE EFFECT OF *Climatic Varieties* UPON GERMINATION

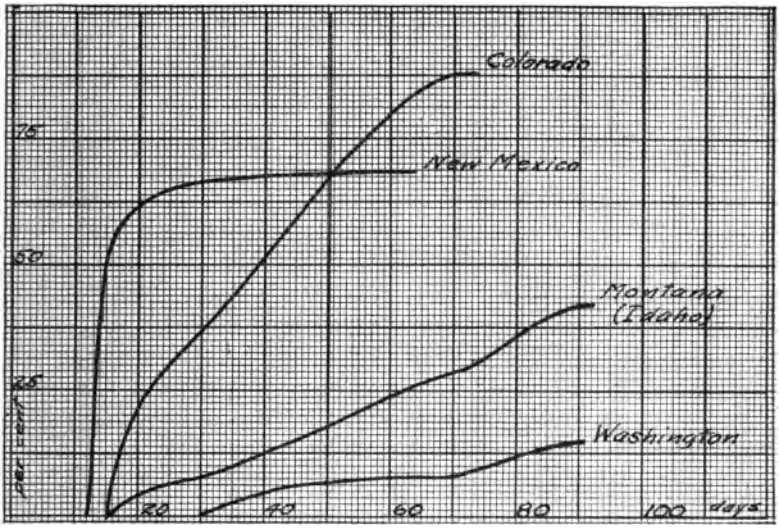

FIG. 1. The germination curves of *Pseudotsuga taxifolia*.

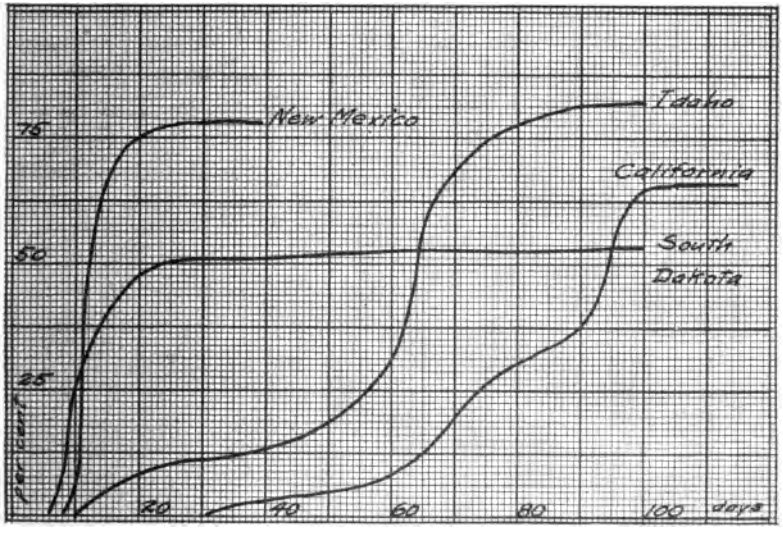

FIG. 2. The germination curves of *Pinus ponderosa*.

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Size, Cm.	Seedlings from Seeds: Small	Large
0–0.5	2	0
0.6–1.0	10	0
1.1–1.5	17	6
1.6–2.0	26	14
2.1–2.5	24	19
2.6–3.0	25	25
3.1–3.5	30	26
3.6–4.0	23	31
4.1–4.5	15	17
4.6–5.0	11	15
5.1–5.5	8	13
5.6–6.0	4	12
6.1–6.5	3	9
6.6–7.0	0	8
7.1–7.5	0	2
7.6–8.0	1	2
8.1–8.5	1	0
8.6–9.0	1	1
Total	200	200

It will be seen that most of the plants from the small seeds fall between the limits 0.6 and 5.0 while most of the plants from the large seeds fall between the limits 1.6 and 6.0. In other words a greater per cent. of small plants were found among the plants that germinated from the small seeds. The average difference in size of 200 plants of each kind was 0.84 cm. in favor of the plants from the large seeds.

The measurements taken for another climatic variety of *Pinus ponderosa* were as follows:

Pinus ponderosa (South Dakota)—Age, 4 Days

35 seedlings from small seeds averaged ..... 4.6 cm.
51 seedlings from large seeds averaged ..... 5.6 cm.

Here there is a difference of 1.0 cm. in favor of the seedlings from the large seeds.

Similar measurements were taken in the case of *Pseudotsuga taxifolia:*

Pseudotsuga taxifolia (New Mexico)—Age, 4 Days

100 seedlings from small seeds averaged ..... 3.58 cm.
100 seedlings from large seeds averaged ..... 4.27 cm.

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These 200 seedlings were classified according to their total length as follows:

Size, Cm.	Seedlings from Seeds	
	Small	Large
0–0.5	0	0
0.6–1.0	0	0
1.1–1.5	1	0
1.6–2.0	9	3
2.1–2.5	7	9
2.6–3.0	20	8
3.1–3.5	19	12
3.6–4.0	12	12
4.1–4.5	10	17
4.6–5.0	11	12
5.1–5.5	5	11
5.6–6.0	5	7
6.1–6.5	1	6
6.6–7.0	0	2
7.1–7.5	0	1
Total	100	100

It will be seen from this table that most of the seedlings from the small seeds fall between the limits 2.6–5.0 while most of the seedlings from the large seeds fall between the limits 3.1–5.5. Just as in the case of *Pinus ponderosa* above we see that the greater per cent. of small seedlings are found among the seedlings that germinated from small seeds. The average difference in size of 100 plants of each kind is 0.69 cm. in favor of the plants from large seeds.

The measurements taken for another climatic variety of *Pseudotsuga taxifolia* were as follows:

Pseudotsuga taxifolia (Colorado)—Age, 4 Days

31 seedlings from small seeds averaged ..... 3.4 cm.
76 seedlings from large seeds averaged ..... 3.9 cm.

Here again there is a difference of 0.5 cm. in favor of the large seeds. In comparing *Pseudotsuga taxifolia* with *Pinus ponderosa* it is found that the size of the seed makes a greater difference in the case of the latter species than in the case of the former. Also,

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the difference in both cases is greater for the variety that comes from the drier climate, that is, the South Dakota variety of *Pinus ponderosa* shows a greater difference than the Idaho variety and the New Mexico variety of *Pseudotsuga taxifolia* shows a greater difference than the Colorado. The data here presented upon this phase of the problem, however, are not sufficient to warrant conclusions.

GENERAL SUMMARY AND CONCLUSIONS

I. *The Effect of Habitat Factors upon Germination*

1. *Shade decreases evaporation* and *transpiration* and thereby *increases* the *soil-moisture content* of the superficial soil layers. This increase in soil moisture content is best shown by the accompanying diagram. This conclusion agrees with the results obtained by Stewart and Hasselbring who grew tobacco in shade tents.

2. *Shade accelerates germination,* that is seeds germinate sooner in the shade than in the light. This *acceleration* is *due* to the *increase* in *soil-moisture content* spoken about above.

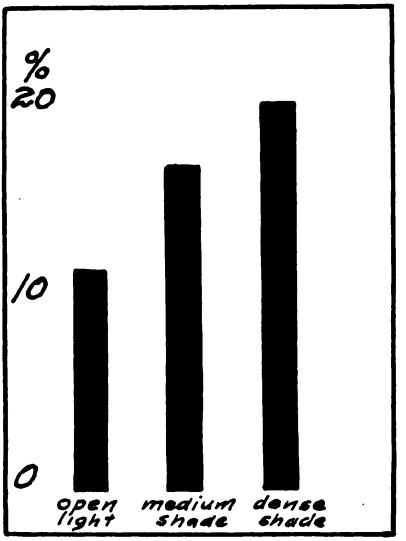

Diagram showing soil moisture content in the three light cultures.

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Burns reached the conclusion that shade reduces the temperature of the soil and delays germination. Evidently there is a delicate balance between soil moisture and soil temperature, so that a slight deficiency in either might delay the germination process. In Burns's case the temperature of the soil was so low, that in spite of the fact that there was sufficient soil moisture, germination was delayed. In the present investigations soil temperature was kept at an optimum and measured differences in soil moisture were sufficient to result in an acceleration of germination in the shade cultures. One unfortunate fact about Burns's work was that he failed to take into account soil moisture. In his experiments it must be assumed that there was sufficient soil moisture for germination. But there is nothing in his report which does not indicate that there was too much soil moisture. The reciprocal relation between soil temperature and soil moisture is well known. Furthermore there is an intimate relation between soil moisture and soil aeration and germination. Such factors as these were evidently not taken into account to explain the delay in germination in the experiments cited.

3. *Shade increases* the length of the germination period. This bears out to a certain extent Pittauer's experiments which showed that germination proceeds more rapidly in the light than in the shade.

4. The *germination curve* of seeds sown in the shade rises *more rapidly* than the curve of seeds sown in the light. This conclusion does not agree with the results obtained by Pittauer.

5. The *final germination per cent.* is usually *higher* in the case of seeds sown in the shade than those sown in the light. This conclusion, based upon abundant evidence, is not in accord with some work done by Atterberg which showed a greater germination per cent. in the presence of light than in the absence of it.

6. *Light plays absolutely no part in the germination of tree seeds;* in fact shade has been found to be exceedingly beneficial to germination, other factors being equal. In the work carried on by Burns already referred to, there are at least two statements that a certain amount of light is necessary for satisfactory germination. Whether he means to imply by the term "light"

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merely the luminous energy or the heat energy of the sun or both is difficult to say. As a general thing it is impossible to have light energy without a certain amount of heat energy, but heat and light affect plants so differently that the final effect of these factors is easily recognized. It is important to keep these two concepts separate in order to avoid confusion. Graves also makes the statement that light is necessary for the germination of Western White pine. It is inconceivable how luminous energy can play any part in germination, especially when the seeds are below the ground; it is likewise difficult to conceive what possible effect light could have if it did reach the seed.

7. An *inadequate* supply of soil moisture *delays* germination.

8. An *inadequate* supply of soil moisture *decreases* the length of the germination period.

9. A *lack* of soil moisture *decreases* the final germination per cent.

10. The germination curves of seeds sown in wet soil rises much *more rapidly* than that of seeds sown in dry soil.

11. Xerophilous species begin germination *first,* xero-mesophilous germinate *later,* and mesophilous germinate *last.*

12. The germination period of xerophilous species is *shorter* than that for either the xero-mesophilous or the mesophilous species.

13. In xerophilous species germination is *accelerated* in the gravel and sand; in mesophilous species it is *accelerated* in loam and sand. In general germination is accelerated in sand and gravel due not to the amount of soil moisture in these soils (see accompanying diagram) but to the amount of oxygen in the soil.

14. The germination period is *longest* in the sand.

15. The germination per cent. is usually *highest* in the sand.

16. The rise of the germination curve of seeds sown in sand is usually *more rapid* than of seeds sown in loam or gravel.

17. According to the table on page 29 of this report the volume of air space in a given volume of soil is about 39 per cent. for gravel, 33 per cent. for sand, and 53 per cent. for loam. In the accompanying diagram is shown the amount of capillary water in these soils at the time of watering and twenty-four hours later.

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This diagram shows very strikingly the water retaining capacity of these three soils. Not only do sand and gravel hold less moisture at the time of watering but they lose a much greater per cent. of it in the course of twenty-four hours than does loam.

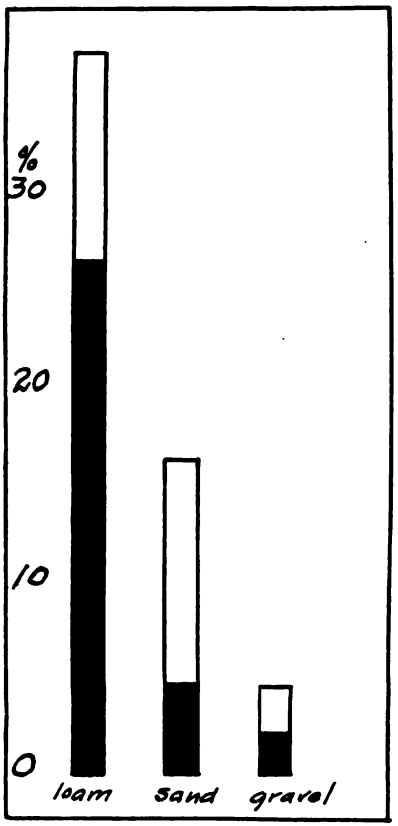

Diagram showing:

□ soil moisture per cent. at time of watering;

■ soil moisture per cent. twenty-four hours later.

When we consider the amount of air space in these soils and the amount of soil moisture each retains, the fact that loam usually contains a great deal of moisture and very little air space and that gravel contains very little moisture and a great volume of air space is very strikingly shown.

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II. *The Effect of Habitat Factors upon Stem and Root Development*

1. *Pinus ponderosa* and *Pinus strobus* show *increased* height growth with *diminishing* light intensity. This conclusion bears out the results secured by Nikolsky who worked with pine and spruce and Burns who worked with *Pinus strobus*. On the other hand Badoux showed that pines decrease their height growth with increasing shade; but these trees were grown to a height of about six feet while Nikolsky and Burns experimented with much smaller stock.

2. *Robinia pseudacacia* and *Quercus rubra* show a *decrease* in height growth with *diminishing* light intensity.

3. *Pinus ponderosa* shows a *decrease* in length of tap root and in total length of laterals with *diminishing* light intensity. These results again bear out the conclusions of Nikolsky and Burns.

4. *Robinia pseudacacia* and *Quercus rubra* show a *decrease* in length of tap root and total length of lateral roots with *decreased* light intensity.

5. *Pinus ponderosa, Robinia pseudacacia, Pinus strobus,* and *Quercus rubra* show *increased* height growth with an *increase* in soil depth.

6. *Pinus ponderosa, Robinia pseudacacia, Pinus strobus,* and *Quercus rubra* show an *increase* in length of tap root but a *decreased* development of lateral roots with *increased* depth of soil.

7. *Pinus ponderosa, Robinia pseudacacia,* and *Pinus strobus* show a *decrease* in height growth with a *decrease* in the soil moisture supply.

8. *Pinus ponderosa* shows an *increase* in length of tap root and an *increase* in total length of lateral roots with diminishing soil moisture content.

9. *Robinia* shows a *decrease* in length of tap root with a *decrease* in soil moisture supply.

10. *Pinus ponderosa* shows the *greatest* height growth in the loam and gravel, but *Pinus strobus* shows the *greatest* height growth in the sand.

11. *Robinia pseudacacia* and *Quercus rubra* show the *greatest*

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height growth in the loam and the *least* in the gravel. Comparing this conclusion with No. 10 it is interesting to see that the conifers do well in either sand, loam or gravel, but that the hardwoods do best in loam only.

12. *Pinus ponderosa,* and *Quercus rubra* show the *greatest* length of tap root and *greatest* length of lateral roots in the gravel and the *shortest* length in the loam; *Robinia pseudacacia* shows the *greatest* length of tap root in the sand and least in the loam. In other words, root development is usually *greatest* in the gravel, and *least* in the loam. This conclusion agrees in part with Tolsky's results that pine in black soils develop vertical roots but in sand develop a greater spread of lateral roots.

13. As far as height growth goes it is evident that pines, on account of their greater drought resistance, may grow as well in sand or gravel, or even attain a greater height in sand or gravel than in loam; while hardwoods which prefer moister soils grow best in loam. That root development is greatest in gravel is due undoubtedly to the fact that water quickly percolates through this soil and hence the roots have to go deep for the moisture. Reference to the diagram on page 85 will bring out these relations more clearly.

III. *The Relation of Size and Weight of Seed to Germination and Early Development.*

1. Large seeds of *Pinus ponderosa* and *Pseudotsuga taxifolia* produce a *higher final germination per cent.* than small seeds. This conclusion contradicts the results of Busse and Centgraf who found no relation between size of seeds and germination per cent., but it proves the contentions of many old silviculturists that large seeds produce a higher germination per cent.

2. At the age of from 2 to 4 days large seeds of *Pinus ponderosa* and *Pseudotsuga taxifolia* produce *larger* seedlings than small seeds. This conclusion proves at least in part Schlich's statement on page 73 concerning the use of large seeds in planting and nursery work and bears out the contentions of practicing foresters in Europe that large seeds should be used in field sowing. This conclusion likewise agrees with the mass of evidence collected in connection with many cereal and garden vege-

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table seeds, namely that the use of large seeds results in a better all round later development and a greater final crop.

3. The Rocky Mountain varieties of *Pinus ponderosa* produce *smaller* seeds, their germination begins *earlier,* their germination period is *shorter,* and their germination curves rise much *more rapidly* than in the case of the Pacific coast varieties of this species.

4. Except for the size of the seed, the same relations hold for the Rocky Mountain and Pacific coast varieties of *Pseudotsuga taxifolia.* Blumer noted the slow germination of *Pinus ponderosa* and *Pseudotsuga taxifolia* from the coast and he also noted the great difference in size of the seed of *Pinus ponderosa.* These observations are corroborated.

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PLATE I

FIG. 1. View of the interior of the greenhouse, showing cultures and hydrothermograph.

FIG. 2. View of the interior of the greenhouse, showing cultures and the cheesecloth tent used for the dense shade experiments.

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PLATE II

THE EFFECT OF *Light* UPON EARLY DEVELOPMENT

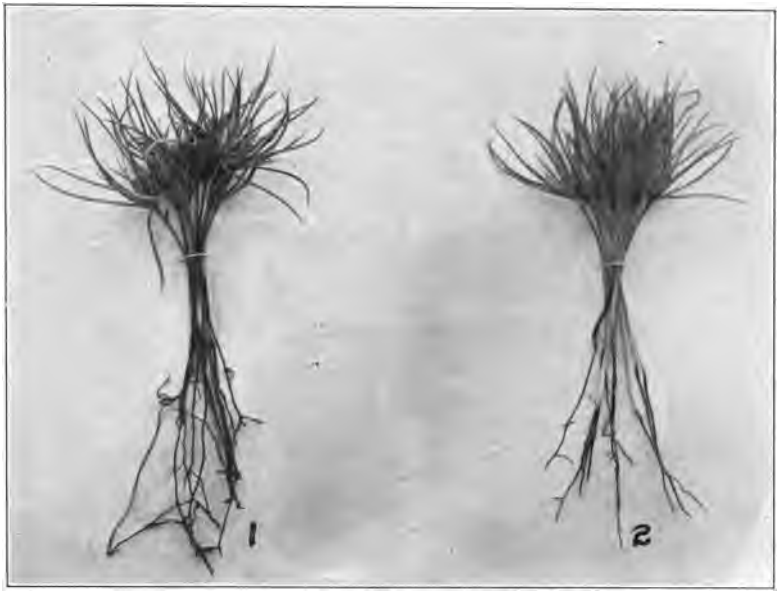

FIG. 1. The effect of *light* upon the development of *Pinus ponderosa* (S. D.). Ten plants each (1) grown in open light, (2) grown in medium shade. 5/8 natural size.

FIG. 2. The effect of *light* upon the development of *Robinia pseudacacia*. Three plants each (1) grown in open light, (2) in medium shade, (3) in dense shade. 3/8 natural size.

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PLATE III

THE EFFECT OF *Soil Depth* UPON EARLY DEVELOPMENT

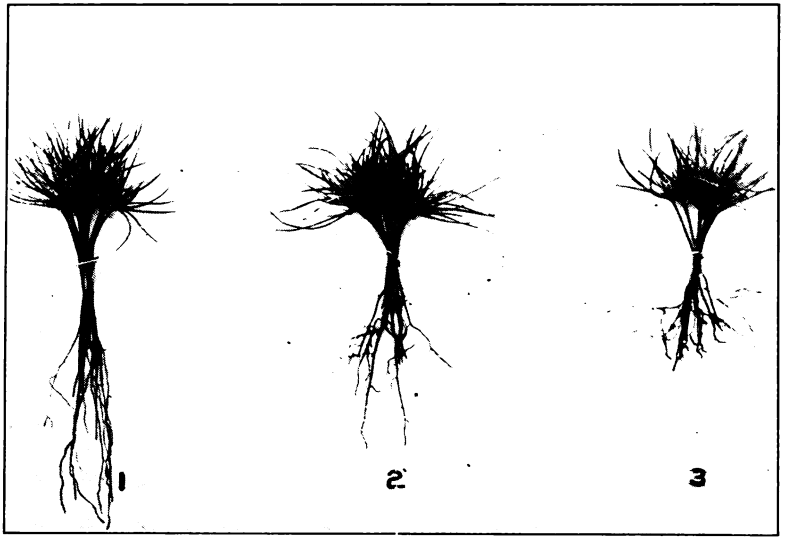

FIG. 1. The effect of *soil depth* upon the development of *Pinus ponderosa* (S. D.). Ten plants grown (1) in deep, (2) in medium, and (3) in shallow soil. ½ natural size.

FIG. 2. The effect of *soil depth* upon the development of *Robinia pseudacacia*. Three plants each (1) grown in shallow, (2) in medium, (3) in deep soil. ½ natural size.

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PLATE IV

THE EFFECT OF *Soil Moisture* UPON EARLY DEVELOPMENT

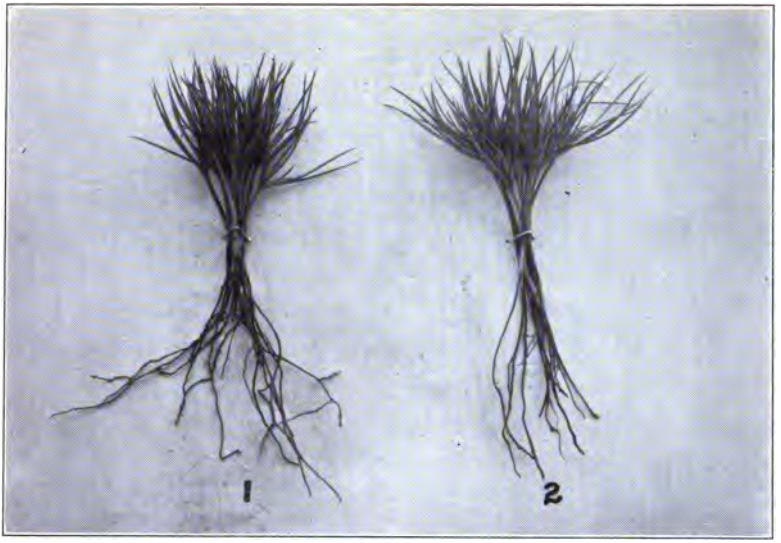

FIG. 1. The effect of *soil moisture* upon the development of *Pinus ponderosa* (S. D.). Ten plants grown in (1) medium dry soil, (2) wet soil. ½ natural size.

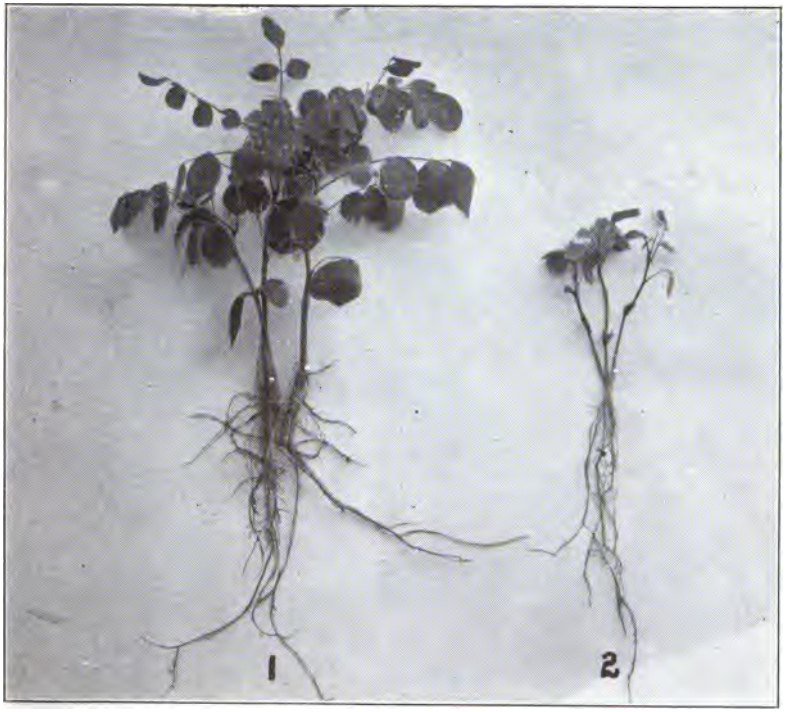

FIG. 2. The effect of *soil moisture* upon the development of *Robinia pseudacacia*. Three plants grown (1) in wet soil, (2) in medium dry soil. ½ natural size.

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PLATE V

THE EFFECT OF *Soil Texture* UPON EARLY DEVELOPMENT

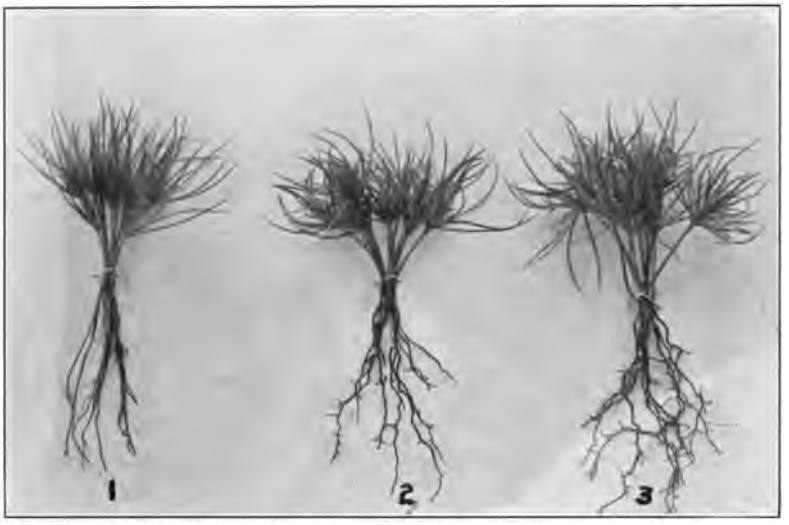

FIG. 1. The effect of *soil texture* upon the development of *Pinus ponderosa* (S. D.). Ten plants each (1) grown in loam, (2) grown in sand, (3) grown in gravel. ½ natural size.

FIG. 2. The effect of *soil texture* upon the development of *Robinia pseudacacia*. Three plants each (1) grown in loam, (2) grown in sand, (3) in gravel. ⅓ natural size.

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II. THE EFFECT OF CLIMATE AND SOIL UPON AGRICULTURE

BY RUSSELL R. SPAFFORD

Field studies in farm management are at present almost wholly confined to measuring the profitableness of a farm business and analyzing the effect of those factors which fall largely within the control of the farm operator. While factors beyond individual control have always been recognized in field work, very little attempt has thus far been made to measure their influence upon farming. It is true that with present weather, soil, botanical, census, and farm management data only preliminary measurements can be made, but nevertheless such measurements do much toward correlating what at present are disconnected facts in agricultural science. The use of these measurements in farm management appears to be of particular importance in a region of low rainfall or low temperature. In a state such as Nebraska it is quite impossible to analyze intelligently either our eastern or western types of farming without first analyzing the influence of natural factors.

The discussion which follows illustrates briefly an analysis of the effect of a few interesting and important variations in climate and soil. In order to give a broad veiw of this analysis the more detailed facts secured from local data have been oriented with respect to broad geographic principles.

The border regions of agriculture in North America, Europe, and Asia are determined by low rainfall or low temperature. In central United States, southern Russia, and western China successful agricultural practices are in harmony with critically low rainfall. In southern Canada and northern Russia they are in harmony with critically low temperature. While moisture and temperature are the chief concerns of border regions, soil fertility is the chief concern of a region well within critical lines.

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Figs. 1, 2, and 3 illustrate the relative importance of moisture, soil fertility, and temperature, as limiting factors in crop production.

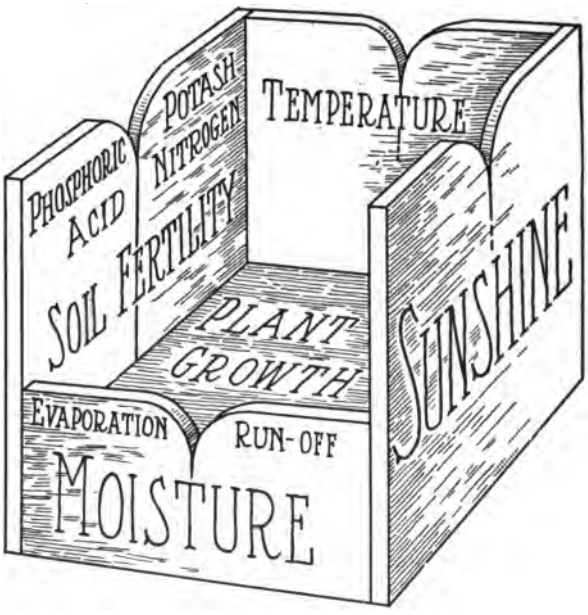

FIG. 1. Moisture the limiting factor in the Great Plains.

Climate and soil are best described as natural factors over which, in the large, we have little or no control. In contrast with natural factors there are so-called artificial factors. These lie to a certain extent within the control of individuals or groups of individuals. Government, organized commerce, and the organization of private business serve as illustrations.

In an early day people of western Nebraska and similar regions were not inclined to look upon climate and soil as fixed. They expected them to be greatly modified as a result of breaking new land and growing cultivated crops. This idea lasted only so long as they lacked actual experience with the country. A few years of effort made it plain that to do profitable farming it was necessary to conform to the natural conditions of the region. This

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conformation has now reached a stage where the organization of farm business may be used as a measure of the effective value of climate and soil.

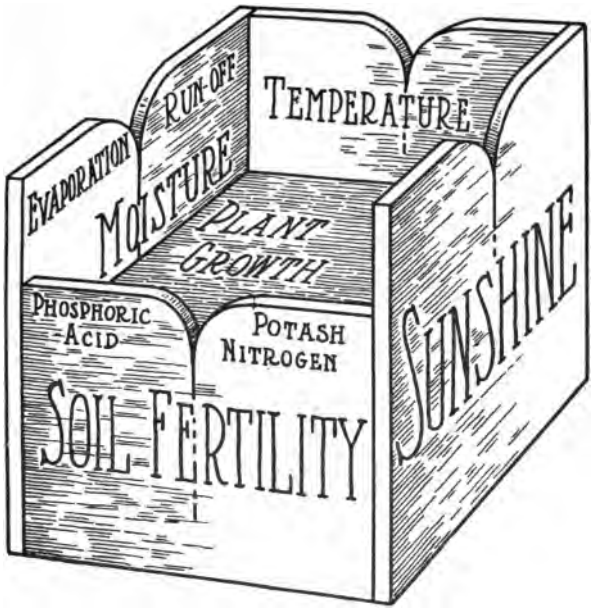

FIG. 2. Soil fertility the limiting factor in the east and similar agricultural regions.

Artificial factors in Nebraska are distributed almost directly proportional to the people. In fact, the relation between the two is so close that it would appear that each individual carried a unit charge of that force necessary to produce what is termed artificial. This is well illustrated by the distribution of our towns and railroads; also by the variation in the size of our congressional districts and counties. If the relation between natural factors, artificial factors, and people were not so close the analysis of the various effects of climate and soil in this state would be more difficult.

During the past three years (1913–1916) Farm Management Surveys have been conducted in Merrick, Fillmore, Gage, Seward,

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Dakota, Thurston, Richardson, Johnson, Box Butte, Phelps, Dawes, and Kimball counties. The adaptation of farm business to natural conditions in these different areas is striking. A contrast of eastern and western farming will illustrate some of the adjustments necessary to meet a marked decrease in the effective

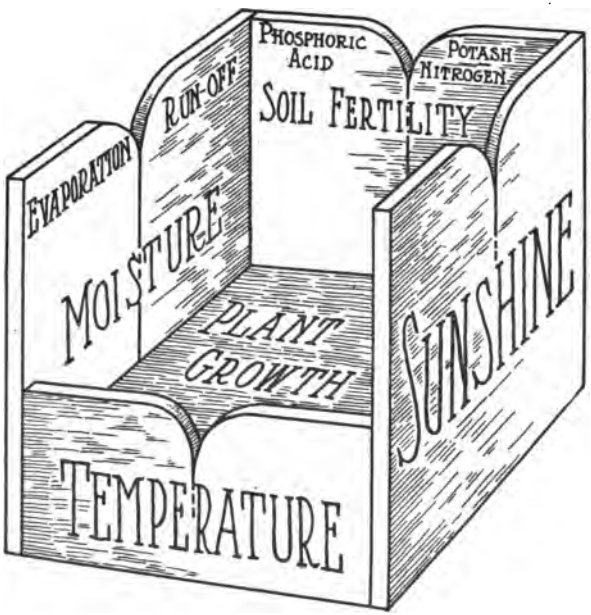

FIG. 3. Temperature the limiting factor in the north.

value of natural factors. Observation and measurements confirm the fact, that of all the elements entering into natural factors, moisture and texture of soil are the most important in this state.

The sparse plant growth on our western uplands compared with the more dense plant growth on adjacent valley or irrigated lands, affords ample proof of the low effective value of moisture in western Nebraska. From a mere observation of these facts, however, it does not follow that well-organized upland farms in western Nebraska are unprofitable. Such facts simply indicate that a very large area is needed to produce plant food sufficient

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for an average family living. For example, on some of the table lands in western Nebraska a section and a half of land at present produces plant food about equivalent in value to that produced on a quarter section of upland in the southeastern part of the state.

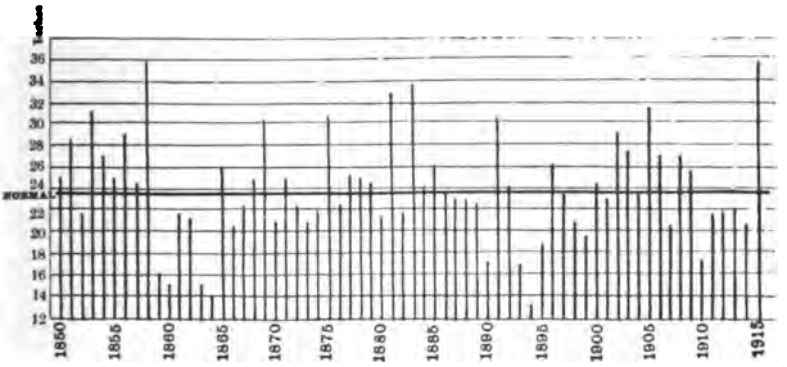

FIG. 4. Average annual precipitation for Nebraska from 1850 to 1915.

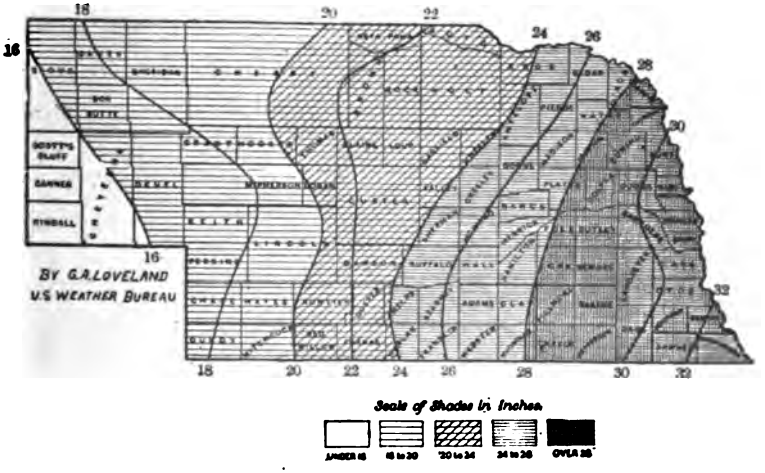

FIG. 5. Average annual precipitation.

Actual measurements show that the total capital, labor, and profits on average farms well adapted to western conditions are about the

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same as on average farms well adapted to southeastern Nebraska. Though a time may come when it will be profitable for people to decrease the average size of farm or increase the average amount

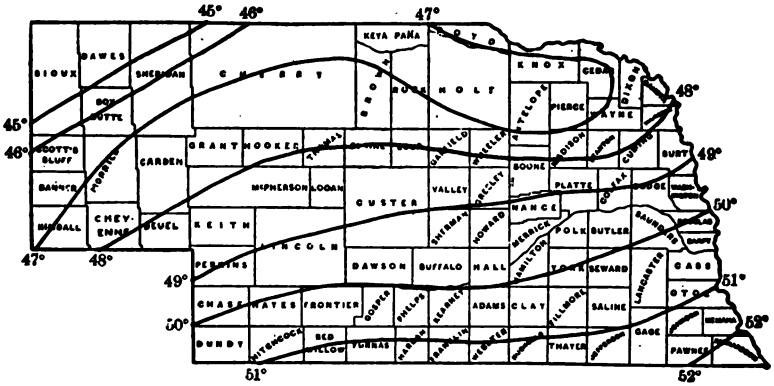

FIG. 6. Mean annual temperature.

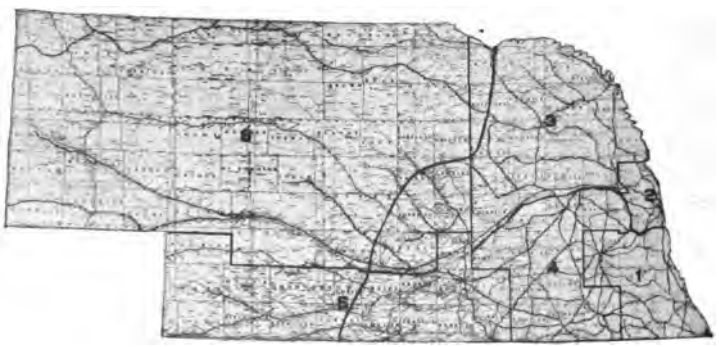

FIG. 7. Congressional district, towns, and railroads. Compare the west half of the map with the east half.

of labor per farm in these two regions, there is good reason to believe that the ratio which now exists between them will not be greatly affected.

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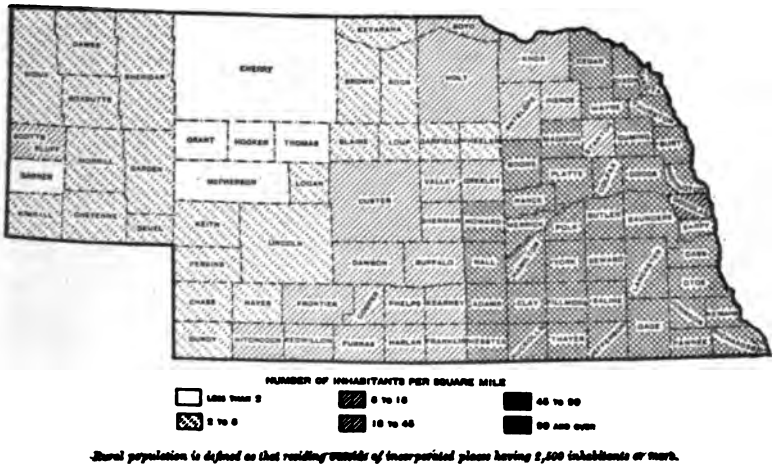

FIG. 8. Density of rural population (census 1910).

Some parts of the above discussion will be made more clear by a graphic illustration (Fig. 10) of average southern Nebraska farms. Soil texture and topography are much the same from Dundy county to Richardson. The differences that exist in soils along this scale are probably slightly to the advantage of the

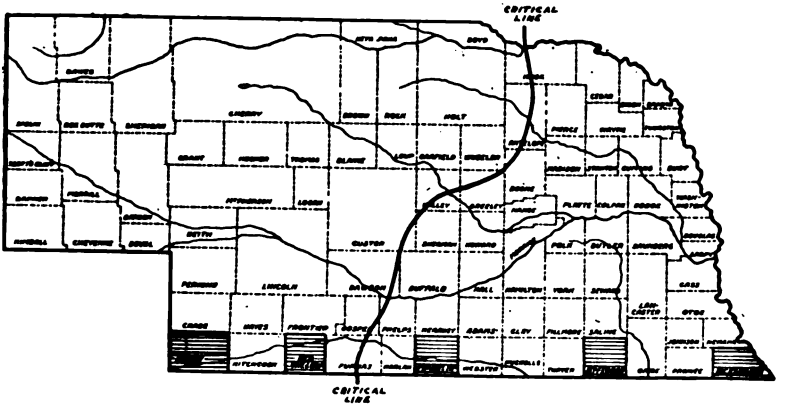

FIG. 9. Counties entering into a scale of study across southern Nebraska.

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DATA ENTERING INTO A SCALE OF STUDY ACROSS SOUTHERN NEBRASKA

County	Dundy	Red Willow	Franklin	Jefferson	Richardson
Rainfall	18 in.	21 in.	26 in.	29 in.	32 in.
Growing season	140 d.	150 d.	155 d.	165 d.	165 d.
Farm area	640 a.	353 a.	235 a.	189 a.	158 a.
Crop area	269 a.	260 a.	193 a.	155 a.	136 a.
Total farm capital	$11,974	$12,708	$13.404	$15,663	$16,092
Man labor per farm	1.6	1.6	1.6	1.6	1.6

coarser and more open soils in the western counties. With important variations in soil practically eliminated, climate in this scale becomes the effective factor. Growing season along our

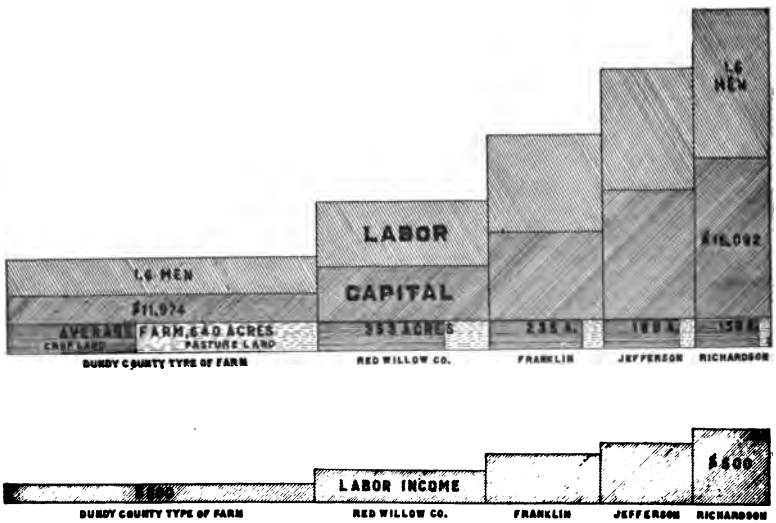

FIG. 10. The organization of southern Nebraska farms. See Fig. 9. (Labor income is a measure of the profitableness of a farm business. It is determined by subtracting farm expenses and a fair rate of interest on capital from the farm receipts.)

southern boundary varies from 165 to 140 days while rainfall varies from 32 to 18 inches. Generally speaking, rainfall below 24 inches or growing season below 125 days becomes an effective limiting factor in ordinary farming. Since nowhere

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along this line the growing season falls below 140 days, the element moisture proves to be the important limiting factor.

In the scale chosen, the size of farm varies from an average of 158 acres in Richardson to an average of 640 acres in Dundy. The technical use of the word *farm* refers to the land directly operated by one man. He may own all the land, rent all the land, or own part and rent part. At first thought it might appear that farms at the western end of the scale are larger simply because the country is relatively new. This cannot be correct, however, for when the government first disposed of the land the average size of farm was nearer 160 than 640 acres.

After long and trying experiences people in the western counties are more and more coming to understand that conditions there are very different from those even a short distance east. But regardless of this fact there is even to-day no clear idea of the rapid change from favorable to adverse conditions after passing the 24-inch line of rainfall. The number of acres required to pasture a horse or cow may be used as a rough measure of this change. To provide five months' pasture for a mature animal in western Nebraska requires about four times the number of acres necessary in eastern Nebraska. From this fact alone it is not out of reason to infer that a decrease in the effective value of moisture reduces the available pasture growth from 1 to about ¼. Man is as dependent upon plant growth as are other animals. All of the food which he consumes is derived either directly or indirectly from plants. Since in Dundy county the effective value of moisture is such that the total usable pasture growth is only about ¼ that in Richardson, it is not surprising to find that the size of farm must be at least four times that in Richardson. Many people though recognizing a decrease in native vegetation in western Nebraska hold strongly to the idea that correct cultivation is the only thing necessary to produce high average yields. All open-minded field studies in this state indicate that in general cultivated plant growth per acre varies quite in harmony with the growth of native vegetation. If it were true that 160 acres of land in Dundy county naturally produced plant food equivalent in value to that produced on 160 acres in Richardson—capital,

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labor, and profits per acre in the two regions would be practically equal. But when it becomes necessary to harvest, either directly or indirectly, four quarter sections in order to gather an economic unit of plant food, it is not surprising to find that capital, labor and profits per acre are cut down to about one fourth.

The adjustment of farm business to conditions of climate and soil is so complete in Nebraska to-day that it is not far wrong to state that the price of land in area X is to the price of land in area Y as the profitable size of farm in area Y is to the profitable size of farm in area X. This proportion is a fair index even where the ratio of land prices is as extreme as $6.00 to $125.00 per acre. Judging from farm surveys there is good reason to believe that at present an average profitable farm business in western Nebraska can be conducted on about 85 per cent of the capital necessary in eastern Nebraska. This is in a large measure due to the fact that where plant growth is sparse and farms of necessity become large, business, educational, and social advantages fall to the point where people hesitate to settle unless financial returns are proportionately increased.

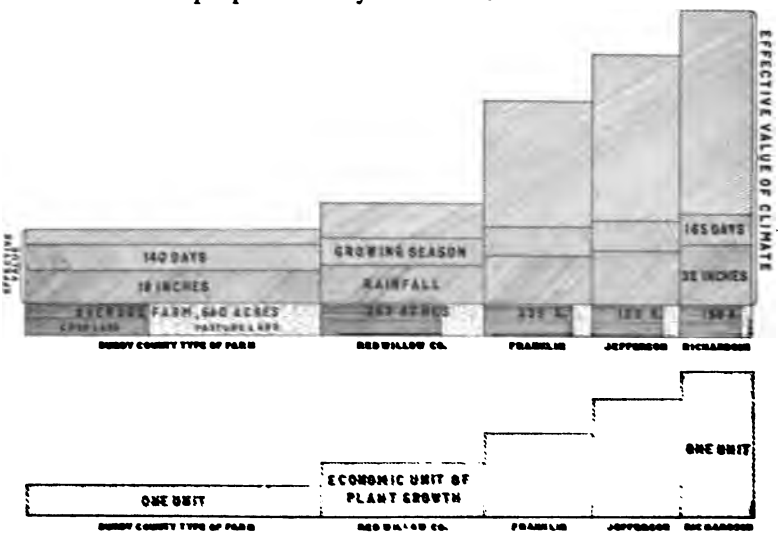

FIG. 11. Effective value of climate measured in terms of plant food having economic value.

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Fig. 10 might be described as artificial accounting with soils under a range of effective moisture variations. In contrast with artificial accounting an attempt is made in Fig. 11 to illustrate what might be called natural accounting. The proportions of this figure are correct in so far as the size of farm in this region is a function of natural factors. Furthermore, since soil, temperature, and sunshine are not limiting elements in this scale the variations observed can be attributed largely to moisture.

Using the size of farm as a function of natural factors it is possible to illustrate, with a fair degree of accuracy, the effective value of such elements as moisture, temperature, and soil. Under the head of soil it will be possible to isolate some of the effects of topography and texture.

Lines 1, 2, 3, 4, and 5, Fig. 12, serve as indexes to graphs shown in Figs. 13 and 14.

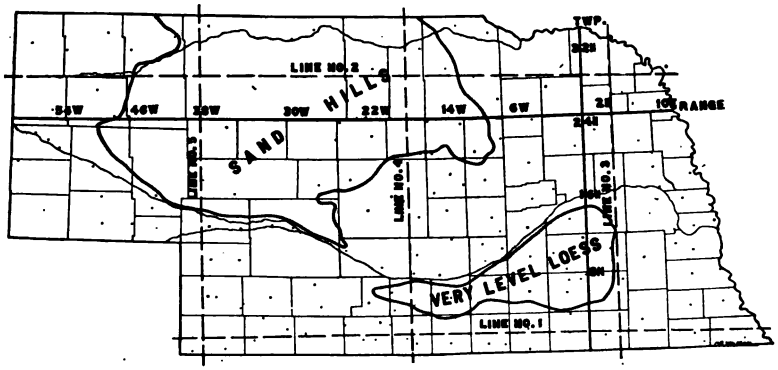

Fig. 12. Key to graphs shown in Figs. 13 and 14. The soil areas indicated are the ones having the greatest effect upon the trend of the graphs.

It will be observed that the rate of change in Graph No. 1, Fig. 13, increases rapidly after passing Range 22 W. Graph No. 2 indicates the rate at which size of farm changes across northern Nebraska. In this graph a rapid increase in the rate of change is observed just west of Range 6 W. It is significant to observe that both graphs show a rapid rise as soon as mean annual precipi-

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tation drops below 24 inches. If it were not for sand hills between Range 46 W and 6 W in northern Nebraska, Graph No. 2 would probably follow parallel to and 50 to 100 acres above

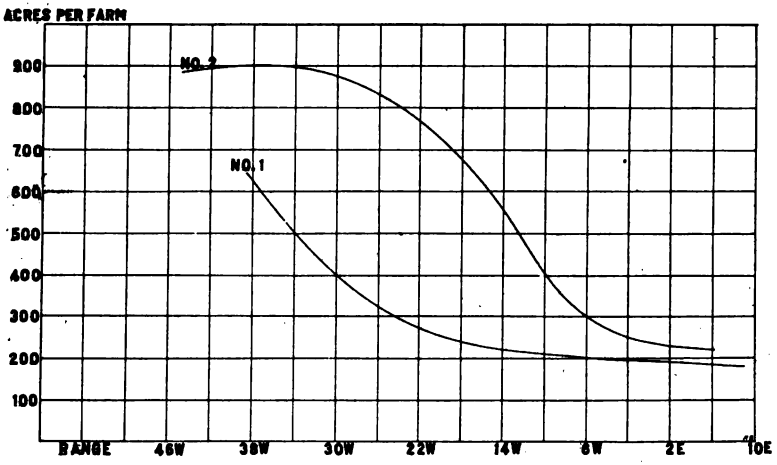

FIG. 13. Graphs illustrating the rate at which size of farm changes along east and west lines in Nebraska. (See Fig. 12, lines 1 and 2.)

Graph No. 1. Any effect due to lower temperature must lie within this narrow margin. From these observations it would seem that though temperature in this state has an important effect upon certain farm enterprises, it has but comparatively little effect upon farming as a whole.

Graphs along north and south lines in the state (Fig. 14) will serve as a partial check on conclusions drawn from a study of variation along east and west lines.

Graph No. 3 across eastern Nebraska lies well east of the line of critical moisture. But for the effect of extremely level land reducing the size of farm near T 8 N, and for the effect of rolling land together with slightly sandier soil increasing the size of farm near T 24 N, there is little fluctuation. Judging from these measurements topography has at least as important an effect upon size of farm as temperature.

Graph No. 4 is typical of central Nebraska. A slight decrease

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in the size of farm south of T 8 N is caused by level upland and the Platte Valley. North of T 8 N critical moisture and sand hills cause an abrupt increase in the size of farm.

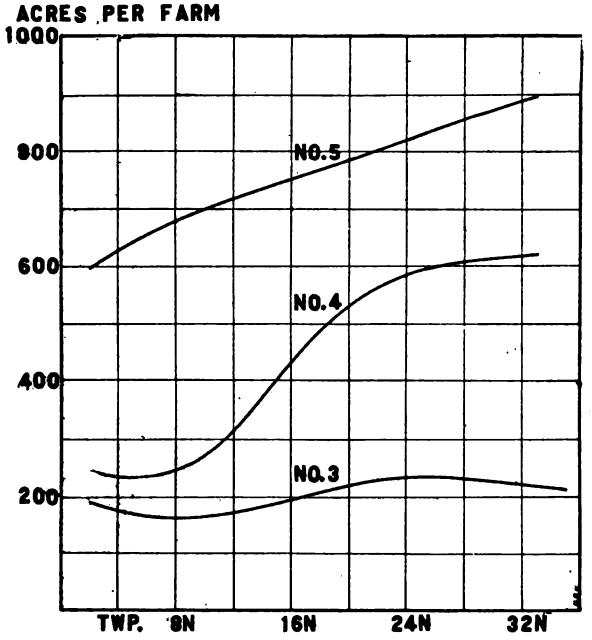

FIG. 14. Graphs illustrating the rate at which size of farm changes along north and south lines in Nebraska. (See Fig. 12, lines 3, 4 and 5.)

Graph No. 5 is a composite of several drawn for western Nebraska. Moisture gives it its position relative to graphs No. 3 and No. 4 while topography and soil texture are the principal elements determining its trend.

Though the above study is based largely on Nebraska data it has more than a local bearing. Moisture problems from southern Texas to the head of the Mississippi river are closely related. To the south they are influenced by high temperature, while to the north they are modified by low temperature. From the head of the Mississippi northwest into Saskatchewan and Alberta a

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lobe of favorable summer temperature determines, to a large extent, the boundaries of the Canadian agricultural area recently opened. In the southern part of this lobe the problems of low temperature are more commonly blended with problems of low rainfall than is true farther north.

Figs. 15, 16, and 18 illustrate the approximate location and nature of critical agricultural lines in the northern hemisphere.

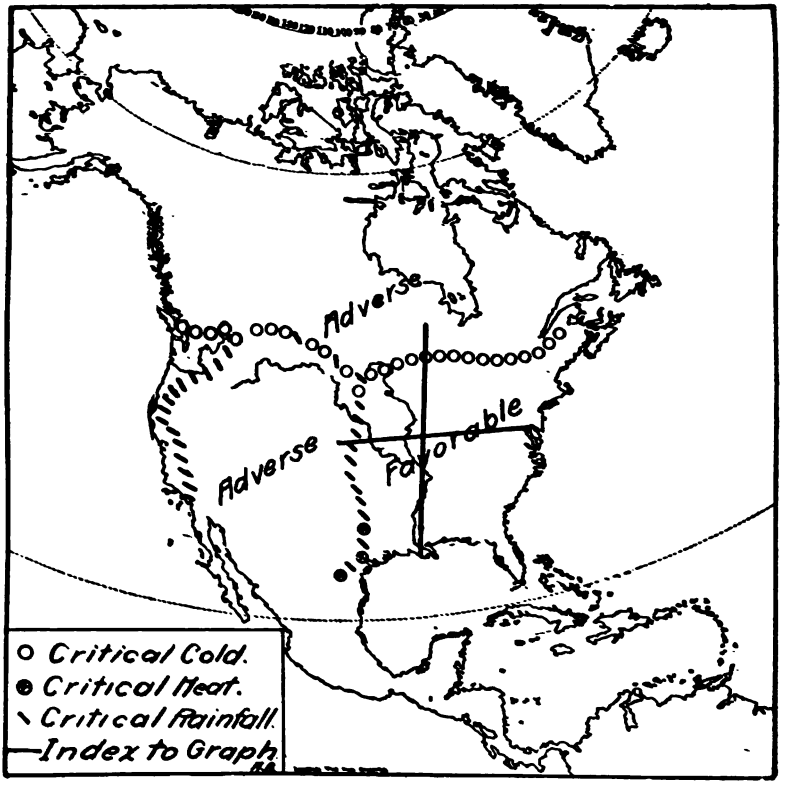

FIG. 15. Critical agricultural lines in North America.

The distribution of native vegetation relative to these lines is very marked. The boundary lines of agricultural regions thus far well developed follow closely the boundaries between northern

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coniferous and broad-leaved forests, the boundaries between temperate and semi-desert grass lands, and the boundaries between northern coniferous forests and semi-desert grass lands.

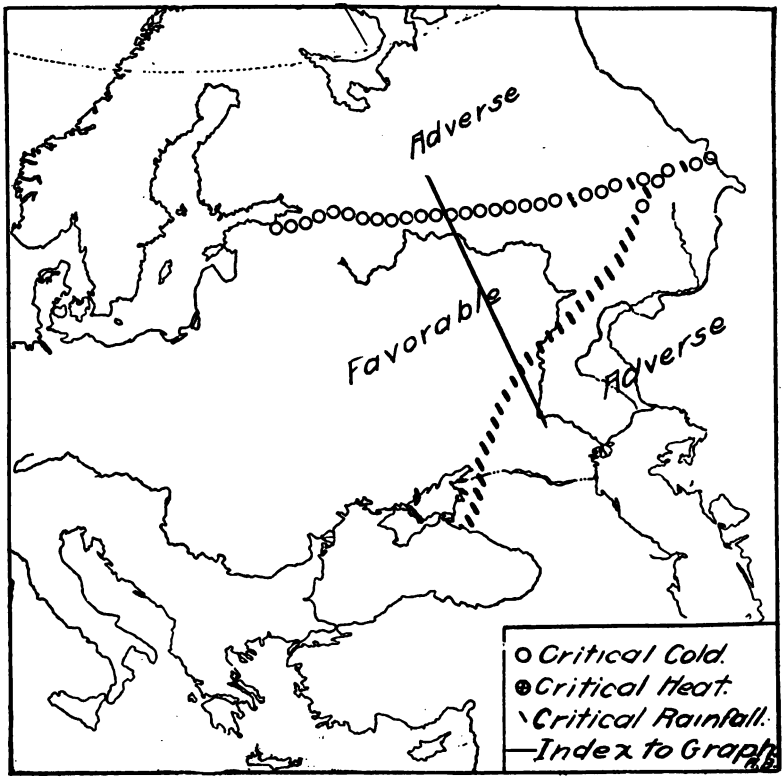

FIG. 16. Critical agricultural lines in Europe.

The natural factors which give such striking characteristics to the distribution of native vegetation give equally striking characteristics to the distribution of people and the organization of farm business. A study of graphs based upon the area of land per person in the United States (Figs. 18 and 19), Russia (Fig. 20), and China (Fig. 21) will serve as a general index to the rate at which the organization of farm business changes near

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critical lines. It is interesting to observe that the rate of change in Europe and Asia is much the same as in America.

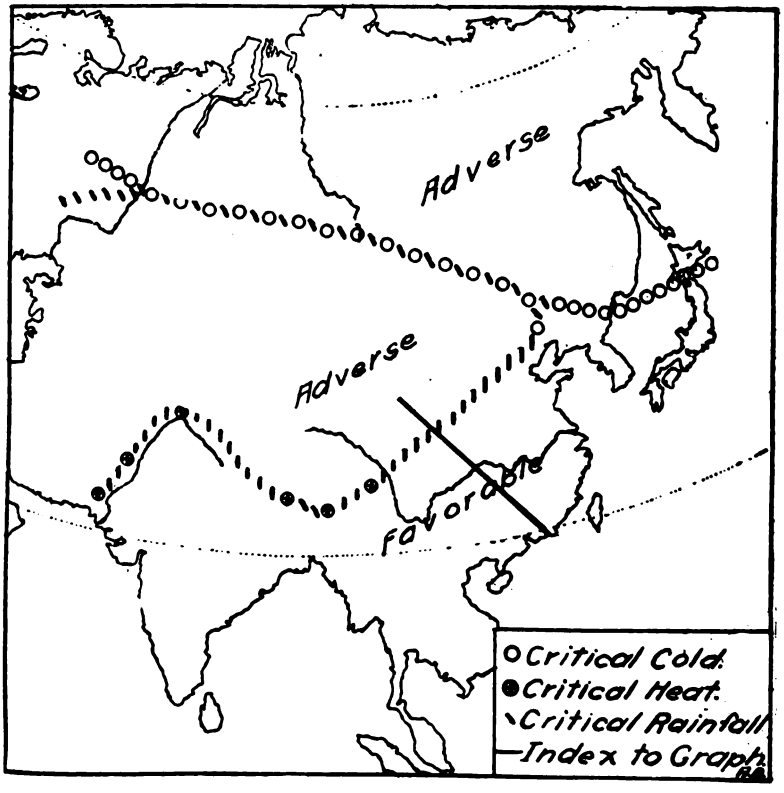

FIG. 17. Critical agricultural lines in Asia.

In the United States it has been a common experience of thrifty farmers from such states as Ohio, Indiana, and Illinois to fail for a number of years while learning to farm in regions of low rainfall or low temperature. It is not uncommon in the drier parts of the west to-day to hear a farmer say: "I sold my place back east and came to this country with enough money for a good start, but I lost it all, and now I'm just beginning to make it back." A review of the experiences of such men invariably reveals the

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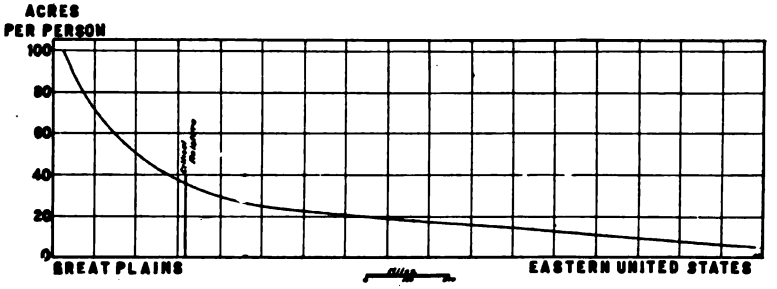

FIG. 18. Land per person increases rapidly near the line of critical moisture. (See Index to Graph, Fig. 15.)

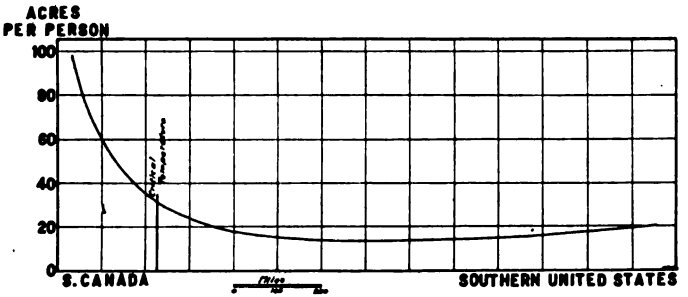

FIG. 19. Land per person increases rapidly near the line of critical temperature. (See Index to Graph, Fig. 15.)

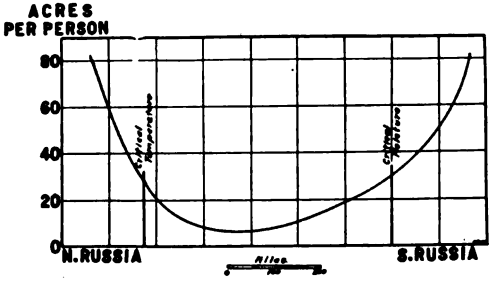

FIG. 20. Land per person from northern to southern Russia. (See Index to Graph, Fig. 16.)

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fact that they are to-day conducting their business on a plane very different from that on which they made their first attempts. Misconceptions regarding the plane of profitable business on the adverse side of critical lines are not wholly confined to the prac-

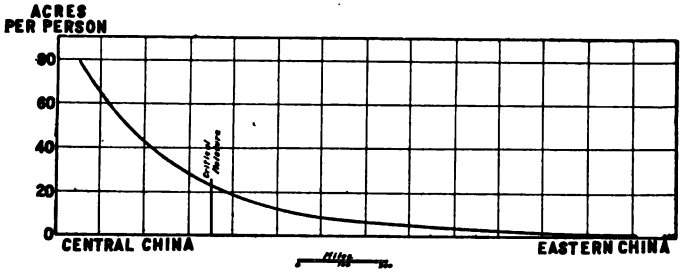

FIG. 21. The effect of critical moisture in China. (See Index to Graph, Fig. 17.)

tical agriculturist. Scientists working on the problems of our border regions have not infrequently had experiences somewhat similar to those of eastern farmers. The same may be said of large business organizations—as for example, loan companies. It is gratifying to observe, however, that general farm experience supplemented by scientific study is gradually solving a number of the most difficult problems peculiar to border regions.

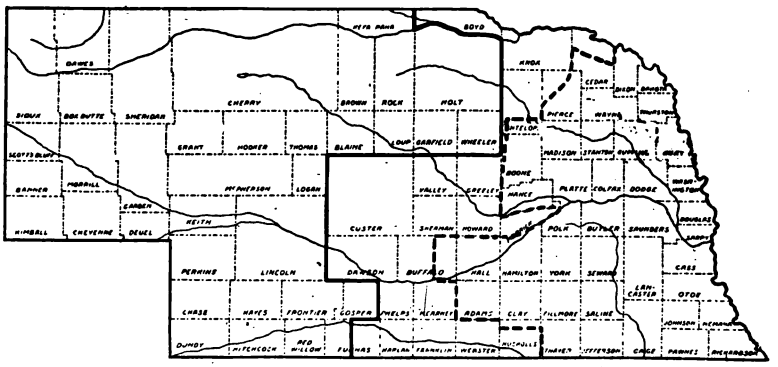

FIG. 22. Insurance companies have hesitated to make loans in western Nebraska. The solid line shows what at one time was the western limit for the Union Central Life Insurance Company. The broken line marks what at one time was the western limit for the Northwestern Life Insurance Company.

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A clearer understanding of what constitutes a profitable farm business west of the line of critical moisture will in time do away with much of the element of risk now entering into loans made on western land.

Observe the relation which lines on this map bear to lines indicated on the following maps.

FIG. 23. The distribution of telephone lines is affected by critical moisture and critical temperature. Compare the figures with Figs. 22, 24, 25.

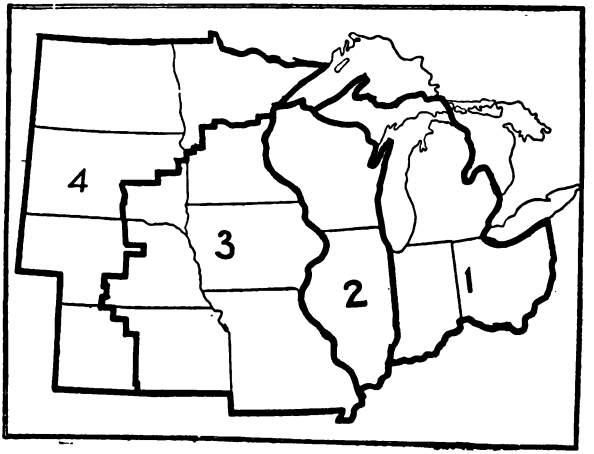

FIG. 24. North Central States divided into four areas according to type of farming. Division made by the Office of Farm Management, Washington, D. C., in recent fence investigations. (U. S. Dept. of Agriculture Bulletin 321.) Compare this figure with Figs. 22, 23 and 25.

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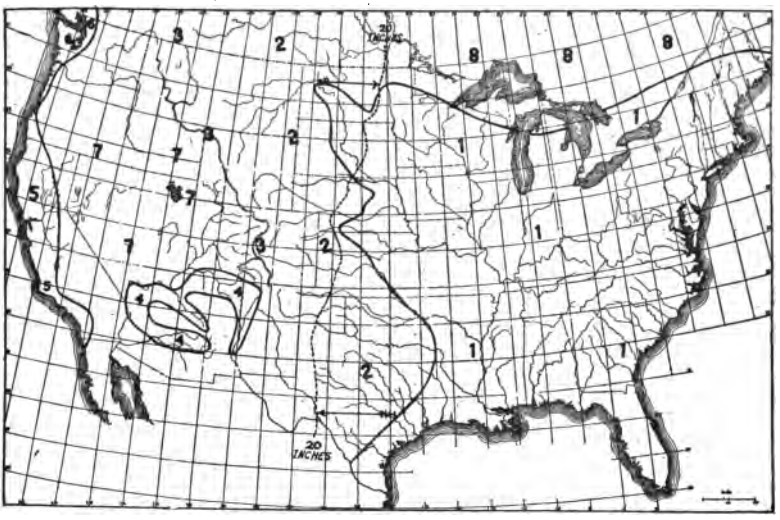

FIG. 25. This map is made to show the regions of more or less stabilized aboriginal occupation in the United States and Canada. In the region numbered (1) on the map, including the eastern half of the United States and a part of the lake and St. Lawrence region of Canada, the aboriginal inhabitants had fixed abodes, lived in permanent houses and cultivated crops of corn, beans, squashes and pumpkins, sunflowers and tobacco. From their permanent villages they made excursions into adjoining regions at certain seasons in quest of various desired products of the native resources. Thus at the western border of region number (1) the village inhabitants made hunting excursions into region number (2) in quest of their supply of meat and other animal products, and also certain vegetable products not available in the region of their fixed homes. They even traveled to region number (3) for some desired products, for example, the lodge pole pine for tent poles, and certain minerals, as obsidian, chalcedony, bentonite, and various other earths and clays.

The tribes resident in region number (2) did not have fixed abodes for the reason that the physical condition of the region did not favor or even permit the cultivation of crops. The supply of their requirements was meager in this region, and had to be sought over a greatly extended range.

The tribes of region number (4) lived in fixed abodes, subsisting by irrigated agriculture. Thus they were found by the Spaniards, the first comers from Europe. The native irrigation works of the region were of great antiquity.

The California region, numbered (5), was one of secluded valleys, the physical control producing community life in fixed abodes.

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Region (6), surrounding Puget Sound, was a region of village life, the factor of control in this case being the fisheries. The houses of this region were built of wood from the abundant forest growth.

Region number (7), the Great Basin, and number (3), the Rocky Mountain region, for the purpose of this discussion may be considered similar, in that the meagerness of natural products in both necessitated a thin and mobile population.

There remains to mention region number (8), the Northern Woodland, in which the climatological conditions prevented aboriginal agriculture and necessitated a mobile population, moving about with the seasonal production of various resources which controlled their economic conditions.

(By courtesy of Dr. M. R. Gilmore.)

Compare the figure with Figs. 15, 22, 23 and 24.

A study of Fig. 26 will serve to summarize the foregoing discussion and at the same time orient it with respect to broad geographic principles. The curves drawn illustrate the relation which artificial factors bear to climate and plant growth.

The increase of plant growth from desert to tropical regions is represented by an increase in the height of the shaded areas.

(*a*) The first graph based upon the density of plant growth illustrates the ease with which man can gather plant food.

(*b*) The second graph is, in a sense, the complement of the first. In regions where plant growth is sparse man is dependent upon animals to convert plant food into usable form.

(*c*) With an increase in plant growth there is naturally an increase in the number of inimical plants. In arctic or desert regions weeds and harmful bacteria are relatively scarce and cause man little trouble. In tropical regions they are so numerous that even civilized man is at present unable economically to control them.

(*d–e*) The majority of agricultural people have long been acclimated to temperate conditions. Any attempt to change to a region where a normal body temperature of about 98.6° is not easily maintained results in serious physiological disturbances. These disturbances no doubt lower the vitality of colonists in tropical regions to a point where it has thus far been impossible for them to become independent of climate, and to do what, under

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temperate conditions, would be a normal amount of productive labor.

(*f*) Capital in arctic regions includes little more than a crude home, land of extremely low value, dogs, and a few implements. In temperate regions capital includes a better home, valuable land,

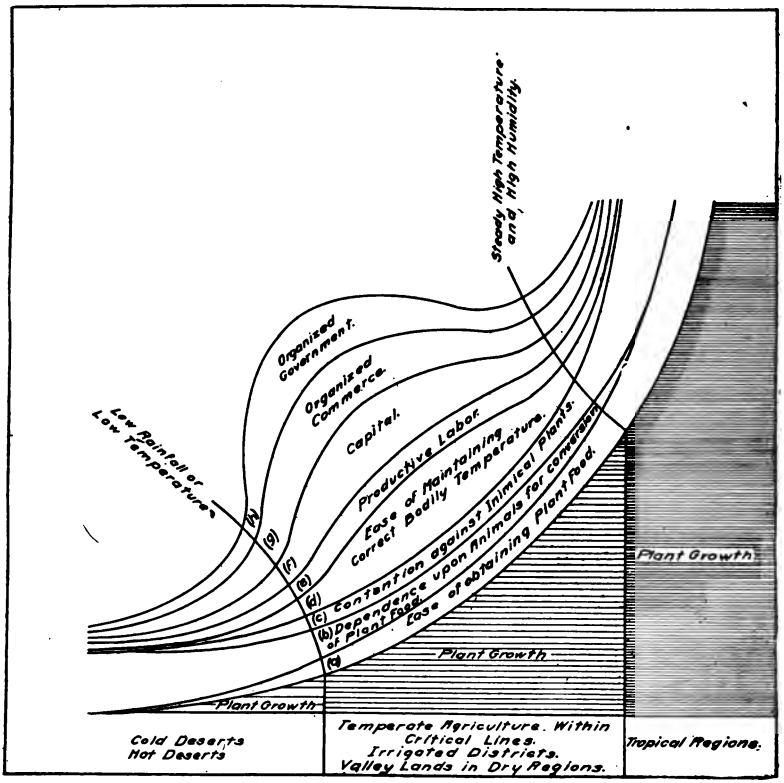

FIG. 26. The relation of artificial factors to climate and plant growth.

more domestic animals, improved implements, and a valued interest in many devices for keeping in touch with people over a wide area. In the tropics capital drops back to a level comparable with that in arctic regions.

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(*g*) Organized commerce falls to the level of barter in regions where people are scattered and productive labor runs low.

(*h*) Highly organized government exists in regions where labor is much divided and people become interdependent.

Without the aid of ideas and material from a number of sources the presentation of matter in this article would scarcely have been possible. I am pleased therefore to make acknowledgment to the following:

Prof. H. F. Williams, Farm Management Extension; Prof. G. A. Loveland, Meteorology; Dr. G. E. Condra, Geography and Soils; Dr. R. J. Pool, Botany; Prof. E. Hopt, Field Crops; Dr. G. O. Virtue, Political Economy and Commerce.

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III.—ON A NEW SUBSPECIES OF PORCUPINE FROM NEBRASKA[1]

BY MYRON HARMON SWENK

Nebraska porcupines all belong to the yellow-haired species (*Erethizon epixanthum*), and these animals have never been abundant in the state. Formerly, however, they were much more numerous than today, and enjoyed a more extended range in the state than they do at the present time. Up to about 1885 these animals occurred across the northern portion of Nebraska east at least to Pierce and Madison counties, there being records of four specimens secured along the small streams tributary to the Elkhorn river in these two counties between 1870 and 1885. Also, in March, 1900, a specimen was killed along the Republican river at Orleans, Harlan county, Nebraska, by Eskey Cobb and is now in the A. M. Brooking collection. As early as 1880 Aughey referred to these animals as being present in the state in small numbers only.

All of the more recent records of the occurrence of porcupines in Nebraska have come from the counties west of the 100th meridian, and mostly from the Pine Ridge of Sioux and Dawes counties and the North Platte valley in Scottsbluff and Banner counties. However, in this study I have carefully examined four mounted porcupines which are in the Rees Heaton collection and which were taken at intervals up to 1903 in Frontier and other western counties. Also, a subadult female porcupine was captured alive with a lasso near the Roseberry ranch in the Cherry county sandhills north of Mullen, Hooker county, September 12, 1914, by Carl Kiehl, quite away from any timber. This specimen was taken to Omaha and sold there, whence it came into my possession by purchase, and is now in the University collection. In August of that same year (1914), a porcupine was killed in a

[1] Publication No. 2 of the Nebraska State Biological Survey.

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cottonwood grove west of the city of North Platte, Lincoln county, about three miles from the river, according to Mr. Wilson Tout. Mr. Tout saw the specimen, which, unfortunately, was not preserved.

In the winter of 1900–1901 a porcupine was reported as killed by a ranchman in the Pine Ridge near Harrison, Sioux county, but was not preserved, and a Plateau Lynx killed in southern Sioux county on February 9, 1916, had numerous porcupine quills in its head. Mr. L. M. Gates writes me that two porcupines were caught in the Ridge near Chadron, Dawes county, during the fall of 1915. But the center of abundance of this animal in Nebraska during recent years seems to be in the North Platte valley. On January 8, 1896, a specimen was received at the University from Scottsbluff county and was mounted for the Museum. During the summer of 1913 Dr. R. H. Wolcott saw a porcupine lying by the roadside in Banner county. On July 28, 1914, Mr. P. P. Wilcox, of Minatare, Scottsbluff county, caught a porcupine in an oats field seven miles north of the town of Scottsbluff, and he kept the animal in captivity in the town of Minatare for a time, but it finally chewed its way out of its cage and escaped. At about the same time Mr. J. N. Wood, of Scottsbluff, captured another specimen in about the same manner. On September 26, 1915, Mr. J. E. Dorothy found a fine old male porcupine in the trees on his farm three miles east of Mitchell, Scottsbluff county, and captured it alive. It was sent to me on September 30 and kept alive in captivity until October 19, when it was killed and added to the author's collection at the University. Later in the fall Mr. F. C. White, a neighbor of Mr. Dorothy, found another porcupine on his farm in a beet field and sent it alive to Hastings College, from whence it was sent to an eastern museum. These, with other records that I have been unable to fully verify, indicate that porcupines are yet surviving in fair numbers in extreme western Nebraska.

In 1877 J. A. Allen pointed out the large size of the porcupines from Wyoming and Montana[2] as contrasted with Alaska specimens. This same characteristic apparently holds true when

[2] *Monog. N. A. Rodentia,* p. 392.

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British Columbia and California specimens are contrasted. A careful comparison of the available Nebraska specimens with the published measurements and descriptions of the various described subspecies of yellow-haired porcupines, and with specimens of the typical subspecies, convinces me that the Nebraska animal may well be separated under the name

Erethizon epixanthum bruneri subsp. nov.

NEBRASKA YELLOW-HAIRED PORCUPINE

Type.—Three miles east of Mitchell, Scottsbluff county, Nebraska, September 26, 1915. ♂ adult (No. 305, Collection of State Entomologist, University of Nebraska). J. E. Dorothy, collector.

Subspecific Characters.—Similar to *E. epixanthum epixanthum* Brandt,[3] of California, but slightly larger, with the hind feet comparativly shorter, the general coloration paler and duller, the under side of the tail largely or wholly brownish yellow, the nasals broader in front and much more narrowed posteriad, the audital bullae larger, and the sagittal, supraorbital and occipital crests less developed, especially in the male; similar also to *E. epixanthum nigrescens* Allen,[4] of northern British Columbia, but slightly larger, general coloration much paler and less blackish, and osseous crests of skull much less developed; larger, with the coloration paler and less yellowish than *E. epixanthum myops* Merriam,[5] of Alaska, and differing further in the larger skull with the brain case broader posteriorly, and other cranial characters; very similar in its pale, dull coloration to *E. epixanthum couesi* Mearns,[6] of Arizona, but with the skull much larger throughout than in the type of that subspecies, and probably the whole animal larger.

Color.—Adult in winter pelage: Upper parts copiously clothed with a fine, soft, woolly, black or blackish underfur which mostly conceals the white, dark brown to blackish tipped quills, which

[3] *Mem. Acad. St. Petersburg,* IX, pl. i (1835).
[4] *Bull. Amer. Mus. Nat. Hist.,* XIX, pp. 521–567 (1903).
[5] *Proc. Wash. Acad. Sci.,* II, pp. 27–28 (1900).
[6] *Proc. U. S. Nat. Mus.,* XIX, pp. 719–724 (1897).

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are abundant everywhere and densely crowded on the neck, shoulders and hips, and become more or less tinged with yellow basally on the sides of the lower back and rump; all of this more or less overtopped with long, straight, coarse, bristle-like hairs which are concolorous with the underfur all or most of their length (pure white at extreme base), the wholly black ones being most numerous dorsally, the others having the apical exposed one-fourth or one-fifth very pale yellowish gray to greenish yellow, these partly yellowish hairs few and scattered dorsally but numerous and with a more pronounced yellow cast on the lower shoulders, sides and especially the flanks, the rump and median area of the upper side of the tail without long hairs; under parts along the midventral line with soft, fine, sooty brownish hairs, these becoming stiffer and white at their bases toward the sides and rather heavily overlaid with the long bristle-like hairs of the overfur, like those above but usually with more extensively white bases; the long, yellowish-tipped hairs of the overfur become stiffer and yellower over the flanks and extend down the sides of the tail as long, very heavy, pale yellow, spinous bristles concealing numerous yellowish white to white quills, the under side of the tail with rather short, exceedingly dense and hispid or spinous bristles which toward the base of the tail are mostly brownish yellow but become increasingly intermixed with black, so that the terminal one-half of the tail is blackish; nose, forehead to interorbital line, a ring around eyes, anterior cheeks, chin and throat covered with short, wholly blackish or brownish hairs, these abruptly intermixed on the forehead and cheeks posteriorly with stiff, appressed, whitish hairs that cover small, white quills and these developing on the occiput and nape to the normal, long overfur hairs and quills; whiskers jet black; legs with the underfur brownish sooty more or less overlaid with greenish yellow to pure gray-tipped hairs. (Description of type ♂; September.)

Adult in summer pelage: Like the winter adult but general color much darker owing to the reduction of the long, greenish-yellow tipped hairs of the overfur which more largely exposes the black underfur. (Description of a living specimen captured at Scottsbluff, July.)

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Immature animal: Like the adult but general color much paler and duller, owing to the very much heavier overfur; with the greenish-yellow apical portion of the long hairs much more extended, involving the exposed one-half to two-thirds of the hairs, so that the general color of the sides, shoulders and neck is almost all greenish-yellow; whitish hairs of forehead and posterior cheeks much more numerous; underfur brownish sooty to brownish black; quills of lower back and rump more yellowish, a clear pale yellow; spinous bristles on sides of tail more strongly yellow, the ventral spinous bristles wholly brownish yellow; legs so heavily overlaid with gray-tipped hairs that the prevailing color of the limbs is gray. (Description of paratype ♀; September.)

Measurements of Type ♂.—Length to end of vertebrae, 797; length to end of tail hairs, 878; tail vertebrae, 202; tail to end of hairs, 283; hind foot, 117. Weight 22½ pounds.

Measurements of Paratype ♀.—Length to end of tail hairs 865; tail vertebrae, 199; hind foot, 98. Near Roseberry Ranch in Cherry county, north of Mullen, Nebraska, September 12, 1914. ♀ subadult (No. 285, Collection of State Entomologist, University of Nebraska). Carl Kiehl, collector.

Erethizon epixanthum was described by Brandt in 1835 from specimens collected in California and Unalaska. Mearns in 1897 selected California specimens as typical of *E. e. epixanthum* in his cranial comparisons with *E. e. couesi,* and Merriam in 1900 described *E. e. myops* from the Alaska Peninsula, thus restricting *E. e. epixanthum* to the California form which he designated as "typical." Evidently, the assumption has been adopted by these two mammalogists that California is the type locality of *E. e. epixanthum.*

Compared, then, with an adult ♀ specimen of typical *E. e. epixanthum* from California (Independence Lake, Nevada county, July 22, 1910, L. Kellogg; Mus. Vert. Zool., 12642) the Nebraska animal is slightly larger (the California specimen is 745 mm. long; tail vertebrae, 200; hind foot, 120), except that the hind foot is comparatively shorter, and the general coloration is paler because the long, bristle-like hairs are mostly pale yellowish gray or greenish-yellow-tipped, with but few wholly black ones

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even dorsally (in *E. e. epixanthum* the wholly black hairs are much more numerous dorsally and the under parts have very few pale-tipped hairs except on extreme sides), while the dense, spinous bristles on the under side of the tail are largely or wholly brownish yellow (wholly jet black in *E. e. epixanthum*).

Compared, also, with the description of *E. e. nigrescens,* which is evidently a form very close to typical *epixanthum,* but blacker, the Nebraska animal is again slightly larger (the adult ♂ type of *E. e. nigrescens* is 740 mm. long; tail vertebrae, 210; hind foot, 90) and differs in coloration much as from typical *epixanthum,* only in even greater degree, since in *E. e. nigrescens* the long dorsal hairs are almost wholly black, with pale-tipped hairs only on the nape, sides of lower back and thighs, while the under parts are wholly sooty black and the long, spinous bristles on the sides of the tail are black, broadly tipped with yellowish white.

From *E. e. myops* the Nebraska form differs, as does typical *epixanthum,* in the paler, less yellow coloration of the pale-tipped hairs of the sides, flanks and sides of the tail, and by the sides of the face and interorbital region being less grayish-haired in the mature animal. It also appears to be a larger animal than *E. e. myops.* *E. e. couesi* is smaller than *E. e. bruneri,* but the two are apparently very similar in coloration.

Compared with an adult ♀ specimen of the Canada porcupine, *E. dorsatum dorsatum* (Linnaeus)[7] from Wisconsin (Sayer, November 11, 1907, E. Heller; Field Mus. Nat. Hist., 16284), the Nebraska porcupine differs in the more abundant long, pale-tipped hairs, which are yellowish gray or greenish yellow in color (comparatively few and white or yellowish white for the terminal one-fourth or one-fifth of their length in *E. dorsatum*), in the long, yellowish bristles on the sides of the tail (much shorter and white or whitish in *E. dorsatum*), in the more grayish legs (mostly black in *E. dorsatum*), in the largely brownish yellow color of the under side of the tail (wholly jet black in *E. dorsatum*), and in the white or yellowish, dusky tipped quills of the lower back, rump and flanks (quills of the lower back and flanks clear white with the extreme tips black, of the rump wholly black,

[7] *Syst. Nat.,* ed. 10, I, p. 57 (1758).

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in *E. dorsatum*). The Nebraska animal is larger than this Wisconsin specimen (which is 790 mm. long; tail 190; hind foot 93) but does not reach the maximum measurements given for *E. dorsatum* by Allen (875–1,000 mm.) and Elliott (900–1,200 mm.). *E. dorsatum picinus* Bangs,[8] from Labrador, with a shorter tail (166 mm.) and longer hind foot (124 mm.) than typical *E. dorsatum,* probably differs in much the same color characters.

Skull.—Measurements of the type in millimeters: Total length, 115.5; basal length, 99; basilar length of Hensel, 95; occipito-nasal length, 111; zygomatic width, 73; interorbital width, 30; length of nasals, 40; width of nasals in front, 21; width of nasals behind, 15.5; length of upper molariform teeth, 27.5; audital bullae, 21 × 16.5; length of mandible, 83; height of mandible, 36.5.

Inasmuch as the skulls of *Erethizon* exhibit considerable sexual variation, for a proper analysis of the characters the skulls of the sexes are better compared separately. The adult ♂ type skull of *E. e. bruneri* compared with the skull of an adult ♂ specimen of *E. e. epixanthum* from California (Whitney Creek, Sierra Nevada mountains, August 26, 1911, Storer and Taylor; Coll. Mus. Vert. Zool., 16216) differs distinctly in its greater length, comparatively shorter and broader rostrum, the much more posteriorly narrowed nasals which are more convex when viewed in profile, larger audital bullae, less developed depression on the top of the skull in the fronto-parietal region, lower lateral borders of interorbital region without any knob-like processes posteriorly, and much less developed sagittal and occipital crests. The ♀ skull exhibits much the same differences, only they are less pronounced. The ♀ paratype skull of *E. e. bruneri* compared with the skull of a ♀ specimen of *E. e. epixanthum* from California (Coll. Mus. Vert. Zool., 12642) though of the same length is distinctly more slender, the nasals are broader and narrow distinctly between the anterior and posterior margins (*E. e. epixanthum* ♀ has the nasals narrower in front than behind and their sides subparallel), and the audital bullae are distinctly larger. The differences in the development of the borders of the interorbital region and the sagittal and

[8] *Proc. New England Zool. Club,* II, p. 37 (1900).

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occipital crests are not very great, though slightly stronger in *E. e. epixanthum.*

Compared with the description of the skulls of ♂ and ♀ *E. e. nigrescens, bruneri* apparently differs, as from *E. e. epixanthum,* in the poorly developed fronto-parietal depression and lateral border of the interorbital region. In these respects the skull of *E. e. bruneri* agrees with that of *E. e. myops,* as well as in the poorly developed sagittal and occipital crests; but the skull is longer and the nasals are more narrowed posteriorly than in *myops,* while the brain case does not narrow posteriorly but rather broadens, and the form of the zygoma and the outer wall of the antorbital vacuity are not as described for *myops* but as these occur in *epixanthum.* The skull of *E. e. bruneri* is much larger than that of the subadult type of *E. e. couesi,* and the audital bullae are as large or even larger than in that form, but the form of the nasals is apparently much the same. In the figures given by Baird[9] of a paratype of *E. e. couesi* (Bill Williams Fork, Arizona, 1854, C. B. R. Kennerly; U. S. N. M., 1262) the nasals resemble those of typical *epixanthum* ♂ and the audital bullae are no more inflated than in *epixanthum;* possibly this specimen really represents *epixanthum* and not *couesi.*

The skull of *E. e. bruneri* ♀ compared with an adult ♀ skull of *E. dorsatum dorsatum* from Wisconsin (Field Mus. Nat. Hist., 16284) reveals considerable similarity, the nasals in both forms narrowing posteriad from the anterior extremity, but these bones are throughout broader and proportionately longer in *bruneri,* more than one-third of the total length of the skull, while in *E. dorsatum* they are less than one-third of the total length of the skull. These differences are even more accentuated between typical *epixanthum* and *dorsatum,* but less so between *myops* and *dorsatum.* The form of the outer wall of the antorbital vacuity in *dorsatum* also resembles that described for *myops* rather than that of *epixanthum, couesi* or *bruneri.*

These cranial differences may be expressed concretely by the following table of typical measurements:

[9] *Mammals of North America,* plate LV, fig. 1, *a, b, c, d* and *e.*

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	Total Length [10]	Greatest Zygomatic Width	Least Interorbital Width	Greatest Length of Nasals	Width of Nasals in Front	Width of Nasals Behind [11]	Length of Upper Molariform Teeth	Audital Bullæ [12]	Length of Mandible [13]	Height of Mandible
F. e. epixanthum. Ad. ♂ (M.V.Z., 16216).....	107	72	29	37	19	18	26	19x15	84	32
E. e. nigrescens. Ad. ♂ (Type, A. M.N.H., 20772).....	105	67	..	..	..	..	26	.....	..	..
E. e. bruneri. Ad. ♂ (Type, U.N., State Ent. 305).....	115.5	73	30	40	21	15.5	27.5	21x16.5	83	36.5
E. e. epixanthum. Ad. ♀ (M.V.Z., 12642).....	98	71	34.25	38	19.5	21.5	24	20.5x16.5	78.5	35
E. e. nigrescens. Ad. ♀ (A.M.N.H.)	104	71	29	..	..	..	28	.....	..	..
E. e. bruneri. Subad. ♀ (U.N., State Ent., 285) .	97.5	67	30.5	34	22.5	20.5	26	22.75x17.5	77	37.5
E. e. couesi. Subad. (♀?) (U.S.N.M., 6501)[14].....	86	64.25	25	30	18.25	15.75	23.75	21x16.7	62.5	29.25
E. d. dorsatum Ad. ♀ (F. M.N.H., 16284).....	96	64	25	29.5	17	15	24	21x17	76.25	33

[10] Distance from front edge of premaxilla to posterior edge of occipital condyles.

[11] Distance across nasals between postero-superior angles of premaxillæ.

[12] The width is taken across the widest point between basioccipital suture and inferior edge of auditory tube.

[13] Chord of the distance from front edge of the mandibular symphysis to the end of the angular process.

[14] Measurements translated into millimeters from Allen, *Monog. N. A. Rodentia*, p. 395, and from the original description of Mearns.

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As to the geographical range of *E. e. bruneri,* I do not have the material or data to indicate except in a very general way. The specimens recorded by Baird from Kansas (Republican

	Total Length	Greatest Zygomatic Width	Least Interorbital Width	Greatest Length of Nasals	Width of Nasals in Front	Width of Nasals Behind	Length of Upper Molariform Teeth	Length of Mandible	Height of Mandible
E. e. bruneri:									
Republican Fork, Kansas. Ad. ♂ (U.S.N.M., 2595)	106	71	31	45	24	18	28	79	38
Republican Fork, Kansas. Ad. (sex?) (U.S.N.M., 2594)	104	71	33	41	..	17.5	27	74	39
Fort Bridger, Wyoming. Ad. (sex?) (U.S.N.M., 3657)	112	78	34	44.5	26	22	30.5	..	..
Wyoming. Ad. (sex?) (U.S.N.M., 11564)	104	72.5	31	38	24	20	28	76	38
Wyoming. Imm. (sex?) (U.S.N.M., 6863)	...	..	26.5	32	20	16	24	72	..
Three Buttes, Montana. Ad. ♀ (U.S.N.M., 13977)	107	71	27	42	22	18.5	26.5	78	36
Three Buttes, Montana. Ad. ♀ (U.S.N.M., 13978)	99	..	31	41	24	19.5	26	73	39
E. e. epixanthum?:									
Idaho. Imm. (sex?) (U.S.N.M., 12405)	95	70	33	37	24	23	27.5	71.5	37
Utah. Ad. (sex?) (U.S.N.M., 3680)	102	77	30	40	21.5	19.5	28	80	38
E. e. myops:[16]									
Fort Yukon, Alaska. Ad. (sex?) (U.S.N.M., 6528)	97	72	33	35	23.5	20	26	79	38
Yukon River, Alaska. Ad. (sex?) (U.S.N.M., 6105)	103	73	31	..	..	..	24	80	38
Yukon River, Alaska. Ad. (sex?) (U.S.N.M., 6104)	104	72	34.5	40	21.5	19	26	80	36.5
Yukon River, Alaska. Imm. (sex?) (U.S.N.M., 6108)	100	70.5	30	..	..	..	26	79.5	35.5
Yukon River, Alaska. Imm. (sex?) (U.S.N.M., 6106)	94	..	33	..	..	..	26	72	33
Peel River, Alaska. Imm. ♂ (U.S.N.M., 6237)	94	73	32	37	21.5	19.5	25	74	34
Peel River, Alaska. Imm. ♀ (U.S.N.M., 6238)	91.5	..	27	32.5	19.5	17	24	71	35
Alaska. Imm. (sex?) (U.S.N.M., 8948)	83	63	32	..	..	..	22	64	30.5

[16] According to Osgood (*N. A. Fauna,* 30, pp. 26, 56 and 80), the porcupines of this region are referable to *E. e. myops.*

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Fork, October 6 and 7, 1856, W. S. Wood, U. S. N. M., 1896–2594 and 1897–2595) from their large size (1896, length 812, tail 162; 1897, length 819, tail 212) and the posteriorly much narrowed nasal bones undoubtedly belong to *bruneri*.[15] The three skulls from Wyoming measured by Allen (F. V. Hayden; U. S. N. M., 3657, 6863 and 11564) are large, and this, with the dimensions of the nasals, indicates that these are also *bruneri*. The two adult ♀ skulls from Three Buttes, Montana, measured by Allen (August 1 and 31, 1873, E. Coues; U. S. N. M., 13977 and 13978) are proportioned essentially like the Wyoming specimens; however, the Montana specimen figured by Baird as representative of *epixanthum* (Fort Union, U. S. N. M., 822; *Mamm. N. A.*, p. 571 and pl. LV) is not only small, being probably immature, but has the nasals nearly as wide posteriorly as anteriorly and is possibly an intergrading specimen with *E. e. epixanthum*. The Idaho and Utah skulls (U. S. N. M., 12405 and 3680, respectively) are apparently also intergrades with *E. e. epixanthum*. The skulls of *E. e. myops* are smaller and have the nasals formed as in *E. e. epixanthum*. The following table has been compiled in millimeters from Allen's measurements, and is appended for comparison.

The writer takes pleasure in naming this new subspecies for Professor Lawrence Bruner, of the University of Nebraska, in recognition of his pioneer work upon the fauna of Nebraska and his continued enthusiasm toward the furthering of our knowledge concerning it. The writer also wishes at this time to acknowledge his obligation to Dr. Joseph Grinnell, of the Museum of Vertebrate Zoology, University of California, for the loan of California specimens of *E. e. epixanthum* for comparison, and for permission to publish photographs of these specimens along with the Nebraska form, and to the authorities of the Field Museum of Natural History for the loan of material representative of *E. d. dorsatum*.

[15] Measurements taken from those given by Baird, *Mammals of N. A.*, p. 571, and Allen, *Monog. N. A. Rodentia*, p. 395.

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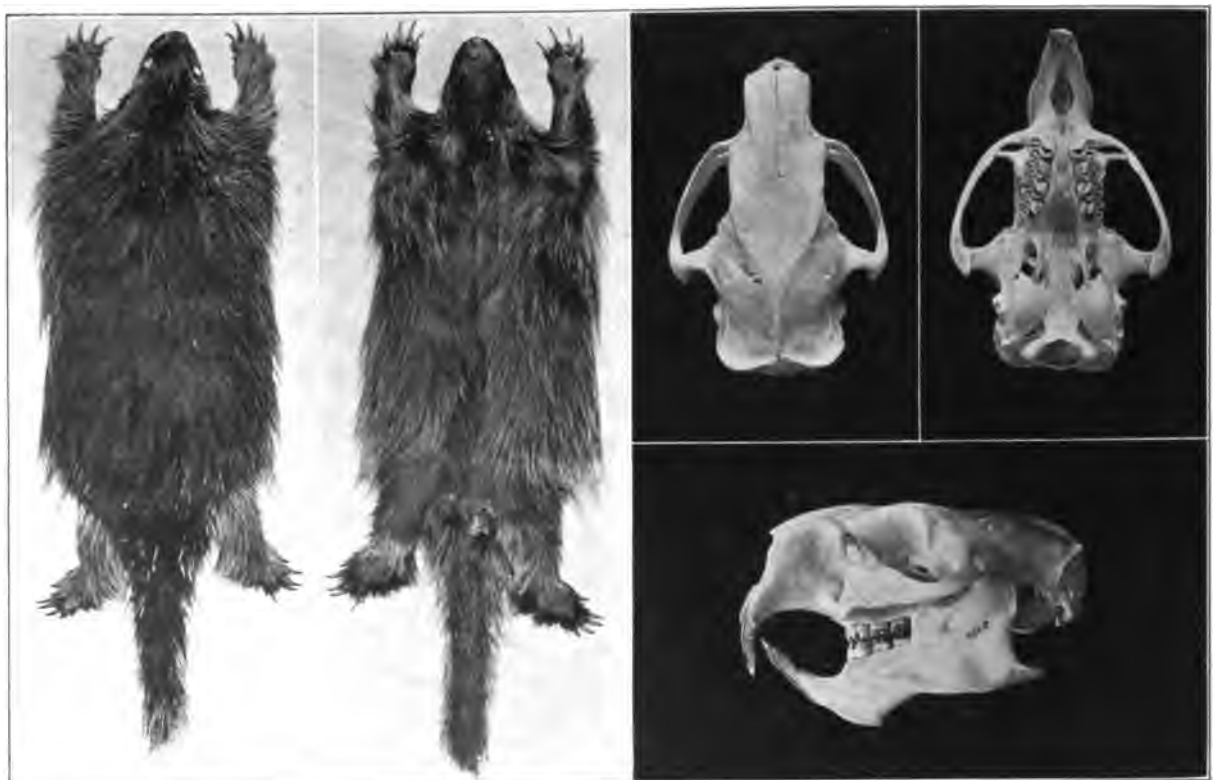
PLATE I.



Erethizon epixanthum bruneri ♂

Type.—Skin one-tenth natural size; skull two-fifths natural size.

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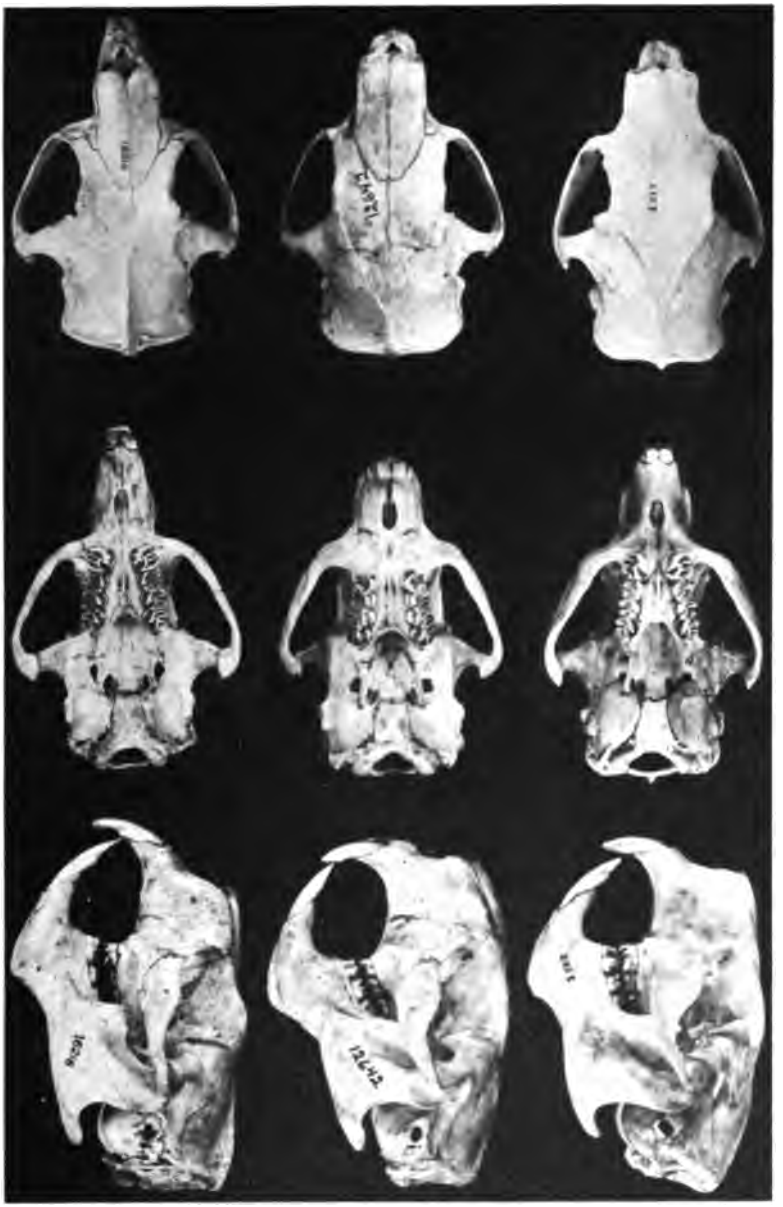
PLATE II.



E. e. epixanthum ♂ *E. e. epixanthum* ♀ *E. e. bruneri* ♀

Skulls two-fifths natural size.

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PLATE III.

E. e. bruneri ♂ *E. e. epixanthum* ♀ *E. e. bruneri* ♀ *E. e. epixanthum* ♀

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UNIVERSITY STUDIES

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A SOCIAL STUDY OF THE RUSSIAN GERMAN

BY HATTIE PLUM WILLIAMS

INTRODUCTORY NOTE

For several years the writer has been engaged in a sociological study of the Russian German community in Lincoln, Nebraska, the results of which will be published ultimately under the title, *The Czar's Germans: a Study of an Immigrant Group in the Midwest.* An understanding of the sociological problems presented has made necessary an extensive historical survey of these people.

The subjects of this study come from the two Volga provinces of Saratow and Samara, located in the southeastern part of European Russia. Their ancestors emigrated thither from various parts of Germany, particularly the southern states, in response to the manifesto of Katherine the Great in 1763. They are a part of the same stream of emigration from Germany which brought the Pennsylvania "Dutch" to the American colonies and which, after the middle of the eighteenth century, was diverted for some years into various European countries.

The Volga "colonists," as they have been called in Russia, have lived, during the past one hundred and fifty years, in their exclusively German villages, retaining their own language, customs, and religion. They have been influenced but slightly by the life about them, and untouched entirely by the great forward movements in the world at large. This is due to the facts that they did not consider the Russian civilization worth emulating, and that they were cut off from the world at large, and from their

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German brethren in particular, by lack of facilities for communication and transportation.

After the freeing of the serfs in Russia in 1861, the various reforms which followed affected the status of the German "colonists." They had gone to Russia under promise that they should have local self-government, retain their own schools and churches, and be free from military service. Now their local self-government was gradually being interfered with, universal military service forced them into the army, and the fear arose that they would in time be denied their German schools and freedom of worship.

Emigration began in the seventies, some going to South America, others to Canada, and large numbers coming to the United States. The latter settled mainly in Kansas, Nebraska, and the Dakotas, all of which at that time were bidding for immigrants. Lincoln was then the distributing center for Nebraska settlers, and has since remained the clearing house for this particular immigrant group. Several thousand Russian Germans now live in Lincoln, forming the largest group of these people to be found in any one city in the United States.

The writer will later make acknowledgment of aid rendered her by many persons, both in the community studied and outside its ranks. She wishes to make grateful recognition at this time of the assistance of Mrs. Henry Heft and family, of Mr. J. J. Stroh in connection with the census of the Lincoln community in 1914, and of Dr. H. P. Wekesser, who read the manuscript of the following pages and gave the benefit of his criticism. Thanks are due to Professor George Elliott Howard under whose direction this study has been pursued, and to the writer's husband, Thomas F. A. Williams, without whose encouragement, suggestion, and criticism the work would not have been possible.

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CHAPTER I

The Population

The history of Russian German immigration to the United States reveals the fact that it has been essentially a movement to the western part of this country and hence to the rural districts. In this respect it differs from much of the present-day immigration which tends to congest in the east, particularly in the large cities. For a study of this nationality, no place in the country offers a better field than does Lincoln, Nebraska, a city of some 48,000 inhabitants, of whom one seventh are Russian Germans. In addition to forming a large proportion of the population, they are a rapidly increasing element in it. In 1914 one third of all the births in the city were of Russian German parentage, while in the preceding year, the total of such foreigners entering Lincoln direct from Russia equalled one and one half per cent. of the entire population of the city.

The location of Lincoln is an added factor which makes it a favorable place for a study of Russian German immigration, situated as it is in the heart of the territory where the greatest number of this group has settled. In the earliest days of the city, it was a distributing point for all immigration to Nebraska, both native and foreign, and small numbers of the first Russian German settlers in the state may still be found in the city. In later years it became the clearing house for a large percentage of the immigration of this nationality to the west; and many of these people have been ticketed direct from Saratow to Lincoln via New York, knowing nothing of any other places in America than these two. After a few years' residence in Lincoln, during which they go to the beetfields each summer, some of them save enough money to start farming, either on rented land in the county or in the vicinity of the beetfields, chiefly in western Nebraska, Colorado, and Montana. Others move to small towns near these regions where they may be close to their work, or out

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to the Pacific coast. Aside from this shifting population there is a large stable nucleus connected with the business and industrial life of the city, and this is being constantly increased as the people rise in the social scale and leave vacant places in unskilled labor for the raw immigrant to fill. Thus Lincoln, on account of its location, furnishes every type of Russian German from the wealthy lumber merchant who came among the first immigrants a generation ago to the most recent arrival from Russia who ekes out a scanty living at street sweeping or at work on the railroad section.

Moreover, Lincoln furnishes an example of the influence of a semi-rural environment upon an immigrant group, a phase of the subject which is seldom treated. Conditions are a cross between city and country, the immigrants being segregated, as in the urban communities of the east, and subject to the political exploitation and the municipal neglect common to great cities. In the formation of educational and political ideals, the influence of Lincoln differs materially from the influence of the country districts in Nebraska where the Russian Germans live; while in industry it partakes more of the nature of a rural locality. On first thought, the circumstances under which the immigant lives in such a community as Lincoln would be pronounced ideal, but in spite of the possibilities which it offers, the relation which exists between the city and its "foreign colonies" is much the same as in the larger cities, and reproduces their immigrant "problem" in miniature.

At every period in American history there has been an immigrant group which has been at the bottom of the social scale. In the colonies, it was the Germans who were feared, despised, and ridiculed. The officials of Pennsylvania were apprehensive lest the government should fall into the hands of these aliens whom Benjamin Franklin is said to have described as "rude boors" and whom the people nicknamed "Dutch." Later, the Irish enjoyed the same prominence, but they are now displaced by the Italians and the Russian Jews. Every community, too, has its foreign outcasts, and those who are accounted aristocrats in one section of the country are anathematized in another. For example, in Pennsylvania where there are so many Slav races congregated at

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present, the Bohemian is a patrician, while in Nebraska, where he is practically the only Slav group, he is considered decidedly plebeian. In the west, another nationality denominated "Russian" occupies the lowest seat in the localities where he has settled, for usually the immigrants of northwest Europe are his only competitors, and he is made to suffer in comparison with them. These local opinions are significant, not because they are well-founded or just, but because they explain in a large degree the relations which exist between these immigrants and the communities in which they live.

In Lincoln the same ignorance, prejudice, and misunderstanding obtain concerning the Russian Germans which invariably exist in American cities having foreign colonies and which too often characterize the attitude of the average American toward the immigrant in general. Many people who have lived in the city for years are ignorant of the fact that the mother tongue of these foreigners is German instead of Russian. Not infrequently some well-meaning citizen suggests that a pamphlet, or address, or bulletin be printed in the Russian language and distributed among the people down in the foreign settlements so that they may get the benefit of it, all unconscious of the fact that not one in a hundred of these persons can understand, speak, or read the Russian language. Others are ignorant of the real character of the people, judging the whole group by the conduct of the few individuals who have a police record. Hence they "would be afraid to go through the settlements alone even in the day time," and they warn anyone who intends to go that they "must be on their guard, for those people carry knives." Even citizens of long residence, ordinarily well informed, are "surprised" at the ability of the children at school, at the neat appearance of the homes, and at everything else commendable which they see on their first visit to the settlements.

A deep-grained prejudice very often exists against these so-called "Russians." Teachers who are sent into these districts resent the assignment, as a rule, and regard it as exile. Certain business men inform you that "they would as soon see the Chinese come here as those people," while others refuse to employ them

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because "they are clannish and quarrelsome and Americans can't get along with them." Even social workers sometimes go into the settlements looking for bad conditions, and they invariably find just what they are looking for—but nothing else. When a Russian German rises out of the ranks of the street sweepers, he is recognized as a "German," while the "Russian" remains the lowest type of laborer and the most hopeless political factor in the city. These misunderstandings persist year after year in a city so small as Lincoln, and with a foreign group where the barrier between the immigrant and the native is so slight as here exists. They account in part for the fact that the Russsian German is an immigrant problem to the city and that the city is a problem to the immigrant.

I. *Composition According to Place of Birth*

The Russian German population of Lincoln is composed almost entirely of immigrants from the Volga provinces of Saratow and Samara. It will be recalled that there are several groups of Germans in Russia, each with individual characteristics accentuated by long residence and isolation in a foreign land. The Baltic Germans, exclusive and aristocratic, have furnished little emigration to America and the few who have lived in Lincoln have belonged to the educated and professional classes. The Germans from South Russia, popularly known as the "Odessers," have settled more largely in the farming districts of the west. There are in Lincoln but nine persons born near the Black Sea and these all came in the early immigration of thirty or forty years ago. Seldom does one of this group come to Lincoln now, and none live within the border of the settlements. The Volga Germans include both Catholic and Protestant, and of the former there are in the city only six families, aggregating twenty-nine people. Aside from a small scattering of persons from other parts of Russia, the remainder of the 6,500 Russian Germans in Lincoln are Protestants direct from the Volga, known among their countrymen as "Volgers." In one sense they form a decidedly homogeneous group which emphasizes their "conscious-

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ness of kind" and sets them off from not only the American, but even the Empire German, element of the population.

However an intimate acquaintance with the Russian Germans reveals a number of types as varied as the immediate localities from which they have come; and different customs, ideals, and characteristics are easily accounted for in this way. The more isolated a community and the less intercourse it has had with neighbors of its own blood and with the outside world, the more accentuated and crystallized its peculiarities become. This has been the experience in the Volga colonies, those living within the same village developing constantly closer ties until they have become as one large family, while all the time the lines between them and the other German colonies have become more sharply defined. No one is so sensitive to these differences as are the Russian Germans themselves. They can tell from each person's dialect the colony to which he belongs; and furthermore, they profess to know certain characteristics of the people coming from each village.[1] This fact must be recognized in a thorough understanding of this group, and therefore a further analysis of the source of emigration is essential.

As has been seen, the two governments of Saratow and Samara, in which are located 181 German colonies, furnish the bulk of the immigrants to Lincoln.[2] Of the foreign-born Russian Germans in the city, seventy-six per cent. are natives of Saratow; eighteen

[1] They often connect nicknames with these characteristics and attach a story to explain their origin. For example, the inhabitants of the colony of Doenhoff are called "Geelbaa'n" (Gelb bein), meaning "Yellowlegs." They are an exceedingly active and busy type of people, as is indicated by the fact that they are the most well-to-do of all the German colonists. Their neighbors tell the story that a villager going to market was once asked by a neighbor woman to take a basket of eggs to sell for her. He accepted the charge, and others then besieged him until his wagon box was filled to the top. But the villagers were still not all accommodated, and not content with what he had already done, the obliging and bustling Doenhoffer jumped upon the load and began trampling down the eggs to make room for more. Hence the name "Geelbaa'n," which in the minds of the German colonists characterizes their countrymen of Doenhoff.

[2] Of these villages, 131 are Protestant, 39 are Catholic, 10 are Mennonite, and 1 is Moravian.

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per cent. of Samara; and six per cent. of other governments in Russia or of other countries. The distribution of the immigrants between these two provinces is further shown in the following:

TABLE I. DISTRIBUTION OF RUSSIAN GERMANS BY PROVINCES AND BY COLONIES

Number of Colonies Furnishing Immigrants		Number of Immigrants Each
Saratow	Samara	
5	1	200–600
2		100–200
4	2	50–100
6	2	25–50
20	38	1–25

The Germans in Samara engage entirely in agriculture, while those in Saratow devote themselves partly to manufactures; but this variation is not reflected in the settlement in Lincoln, as none of its inhabitants follow the occupations which they carried on in their former homes. But these groupings manifest themselves in various ways in the social and religious life of the people, as we shall see in detail later. Aside from peculiarities in dialect and customs, and numerous differences in folklore, they are the basis of local pride and prejudice which break out in petty quarrels often carried into the courts, and in "wedding riots" which sometimes occur during the season of these festivities.

In addition to the immigrants who come direct from the German colonies of the Volga, many coming from other parts of the Empire are traceable originally to that region. A few of these are natives of near-by Russian villages where their parents had gone for work, while others were born on neighboring estates where the father was employed as foreman of a mill or in some similar capacity. A larger number come from the cities of the government Saratow—some from Zaritzyn, but most from the city of Saratow where they have been engaged in various manufacturing pursuits.

Outside the Volga provinces, the Caucasus furnishes the largest number. They come from the German colonies near Tiflis,

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Stavropol, Vladikavkaz, Novorossiisk, and Yelizavetpol, and from the city of Baku. Astrachan and Orenburg in the east of Russia contribute a few, as does Riga in the Baltic Provinces. Several cities in western Russia, which send a large number of Jews to the United States, are represented. Polotsk, the home of Mary Antin,[1] is credited with three natives; while Kiev, Zhitomir, Novgorod Volynsk, and Warsaw each furnish one. Some of these are due to marriages which Russian Germans contracted while stationed at these cities on garrison duty; or probably in some cases as a result of acquaintanceships formed at the emigrant stations on the way to America. There are a few immigrants in Lincoln who were born in Siberia where the Volga Germans have gone in great numbers during recent years, under contract with the government which has been settling large tracts of land there. These were dissatisfied with the conditions they found, and since they had forfeited their place in their village by emigrating, friends have helped them to America. A few of the Russian Germans in Lincoln were born in South America, chiefly Buenos Ayres, where large settlements of their people have been located since the German colonists first began leaving Russia in 1871. In some instances these are people who were refused entrance at Ellis Island on account of trachoma, and who then went to South America where the exclusion acts are not so strict. After a few years there, they apply again for admission to the United States, and are accepted. The last group of foreign-born Russian Germans includes those born on the way to America. Libau, the port of embarkation for much of the present emigration from Russia, is the native place of five; Liverpool, of one; Germany, of one; Quebec, of one; while five were born at sea. Several born at New York and Boston are really included within this latter group.[4]

[3] Mary Antin, *The Promised Land,* Chapter I.

[4] A further analysis of the source of emigration of the Russian Germans in Lincoln is interesting though not of any especial social significance. The following table gives the total number of Russian born Germans according to provinces and villages:

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The first Russian Germans known to have settled in Lincoln

Government Saratow

German Colonies:	
Norka	633
Frank	371
Balzer	352
Beideck	292
Huck	253
Walter	196
Schilling	154
Kauz	90
Franker Chutor	68
Kolb	66
Dietel	60
Doenhoff	45
Walter Chutor	44
Moor	39
Hussenbach	37
Grimm	32
Anton	31
Neu Messer	14
Lauwe	13
Messer	12
Bauer	11
Dobrinka	10
Kutter	9
Sarepta (Moravian)	4
Hiltmann (Catholic)	4
Stephan	4
Pobotschnaja	3
Goebel (Catholic)	3
Schwab	3
Kratzke	3
Dreispitz	3
Marienfeld (Catholic)	2
Merkel	2
Kraft	2
Franzosen	2
Holstein	1
Tscherbakofka	1
Russian Villages:	
Balanda	9
Rybushka	6
Nikolajewka	3
Balashov	2
Shirokaja	2
Achmat	1
Ryudnya	1
Demetrievka	1
Unknown	10
Estates:	
Fahrenbruch Chutor	4
Ust Loba	3
Molans Chutor	2
Trekovka Chutor	1
Russian Cities:	
Saratow	58
Zaritzyn	14
Atkarsk	1

Government Samara

German Colonies:	
Kukkus	243
Laub	94
Warenburg	81
Stahl	40
Jost	38
Wiesenmueller	24
Brunnental	19
Katherinenstadt	17
Schwed	15
Reinwald	3
Raskaty (Catholic)	3
Strassburg	2
Gnadendorf	2
Marienthal (Catholic)	2
Neu Hussenbach	1
Gnadentau	1
Herzog (Catholic)	1
Schaefer	1
Neu Schilling	1

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came in 1876.[5] During the following decade many passed through to join friends in the rural districts of Nebraska, Kansas, or the Dakota Territory and some took up their residence in the city. By 1889 the number of these foreigners was sufficiently large to show initial signs of differentiation from the rest of the community by the organization of a church of 18 families representing 100 individuals.[6] Since the time of the formation of this

Dinkel	13
Eckheim	10
Bangert	8
Gnadenfeld	7
Friedenfeld	7
Rosenfeld	5
Krasnojar	5
Morgentau	5
Straub	5
Urbach	5
Enders	4
Alt Kana	3
Rosenheim	3
Langenfeld	3
Meinhardt	1
Neu Laub	1
Borgard	1
Schulz	1
Neu Marienthal (Catholic)	1
Semenovka (Catholic)	1
Schoendorf	1
Fresental	1
Orlow (Mennonite)	1
Hahnsau (Mennonite)	1
Russian Villages:	
Kosakenstadt	3

The Caucasus	
Government Stavropol	39
Government Baku, Baku	10
Government Tiflis	6
Government Terek	3
Government Kuban	3
Government Yelizavetpol	2

West Russia	
Vitebsk, Polotsk	3
Smolensk, Krasny	1
Poland, Warsaw	1
Volhynia, Novgorod Volynsk	1
Zhitomir	1
Kiev, Kiev	1

Siberia	
Government Tobolsk	2
Government Akmolinsk	1
Government Omsk	1
Astrachan (City)	1
Orenburg (City)	5

Baltic Provinces	
Courland, Libau	5
Livonia, Riga	1

South Russia	
Cherson	7
Bessarabia	2

[5] Cf. *Naturalization Records of District Court of Lancaster County.*

[6] The church records have not been found, and these figures are estimates by some of the charter members.

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nucleus, increasingly large and frequent groups of Russian Germans have been added. This length of residence together with the facts that the immigration has always been a family movement, and that a large birth rate prevails with this nationality, accounts for the great numbers of native born Russian Germans in Lincoln. Out of 5,985 persons whose birth place was given, 36.3 per cent. were born in the United States and 63.0 per cent. in Russia.[7] A very small number of the native born are heads of families and thus furnish an opportunity to mark the effect of American environment upon the second generation born here. The majority of the native born, however, are children and young people under age. Of the native-born children of Russian German parents, 80 per cent. are natives of Lincoln, showing how largely this city has been the distributing point for this nationality.

It has been pointed out frequently that the Russian German immigration to America is a family movement. This is true, not merely in the sense of the individual family consisting of parents and children, but in the larger sense of the undivided or patriarchal family as it exists in the German colonies in Russia. It is a common saying that everybody in the Lincoln settlements is related to everyone else. A child, in response to the question how many of her family came when she did, said, "A whole ship-load." Relationships are recognized to a much more extended degree than with us, and second or third cousins, or relatives by marriage, with the relatives thereby acquired, are counted as a part of one's "family."[8] Endogamy, practiced for a century and a half, has literally made the inhabitants of each village one large family, and when immigration from any one colony begins, it means that a large number of "relatives" will surely follow from that place. Thus six colonies have furnished 60 per cent. of the 3,772 foreign-born Russian Germans in Lincoln, while the remaining 40 per

[7] All statistics relating to the Russian German settlements are taken from or based upon the private census taken in March–April, 1914, unless otherwise stated.

[8] The Russian Germans use the word "freund" as a generic term to mean relative, including all degrees except those represented in the immediate family.

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cent. is scattered among 124 different places. This immigration has not resulted from solicitation by steamship companies or advertising literature, but almost universally from the encouragement of relatives who preceded the immigrant to America. There has been not only the assurance of work and of comfortable living conditions, but the receipt from relatives of steamship tickets, the money for which is repaid out of the first earnings of the family after reaching America. Fathers and mothers, brothers and sisters, aunts and uncles, nieces and nephews, cousins and second cousins, and all of their relatives in turn are thus brought to the "land of the free."

Technically speaking, Russian Germans therefore fall under the head of "assisted" immigrants, *i. e.*, aliens who come on tickets bought in this country and sent to them. Such foreigners are ordinarily considered an undesirable class and their admission is prohibited when they are assisted by a corporation, association, society, municipality, or foreign government. But a distinction is made between such aliens and those whose fares are paid by relatives or friends, although the government still considers the practice unfortunate and not calculated to secure the best results. In 1913, 32 per cent. of all the aliens entering the United States were prepaids, and from 1910 to 1912 the proportion ranged from 25 to 36 per cent.[9] Of the Russian-born Germans living in Lincoln in 1914, however, 65 per cent. had come on prepaid tickets and only 35 per cent. had paid their own passage. In spite of the unfavorable circumstances suggested by these statistics, experience with the Russian Germans in Lincoln, who for twenty-five years have come "assisted," shows that there is no relation between the desirableness or the undesirableness of these immigrants and the fact that their passage is paid for them.

Indeed it does not always indicate even their financial condition. Not infrequently a young married man of a well-to-do family wishes to emigrate, but his father objects and refuses not only to give him his portion of the family possessions but even to

[9] *Annual Report of the Commissioner General of Immigration*, 1913, 18. Cf. also, "Emigration Conditions in Europe" in *Report of Immigration Commission of 1907*, IV, 59–61.

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advance him money for the voyage. The young man then writes to a brother, a cousin, or other relative in America and secures tickets for himself and his family. Immigrants thus assisted are far better off than those who borrow money in Russia. This most often happens when a man leaves home in a great hurry to avoid being caught for military service.[10] He does not have time to dispose of his property advantageously or to wait for a ticket from America, so borrows enough for its purchase from money loaners in Russia. These are usually Jews, and the interest demanded is enormous. On the immigrant's arrival in the United States his relatives or friends secure a new loan for him and he is thus relieved from the necessity of paying exorbitant interest.

Invariably, the purchase price of tickets to immigrants is loaned without interest, since the transaction ordinarily takes place between relatives and is considered purely as a matter of mutual aid. In case, however, the relative is unable to raise the amount from his own funds and the circumstances are urgent, he can secure a loan with interest from one of his well-to-do countrymen. That it is a very rare thing for anyone to lose any money in these transactions, argues well for the assisted immigrants. Moreover, such aid from relatives is the best proof available that America has not made them grasping and selfish in their newly-found prosperity. It is a sign that they are keeping fresh in their minds the condition under which they came to America, and that they remember with gratitude the help that someone lent them. It is when they begin to say that they "need all the money they can make for themselves" that they manifest the unsocial spirit which the materialism of America fosters.

An important factor in any immigration problem is the alien's length of residence in America, which immediately affects his political status, and which is a means of demonstrating his ability to assimilate and to rise in the social scale. In Lincoln, as we

[10] Another type of immigrant who does not come technically "assisted," according to the records, is the criminal who may or may not be aided by his relatives to escape. There are only a few of this class in the Lincoln settlement, but, as a rule, they attract a great deal of attention from the public.

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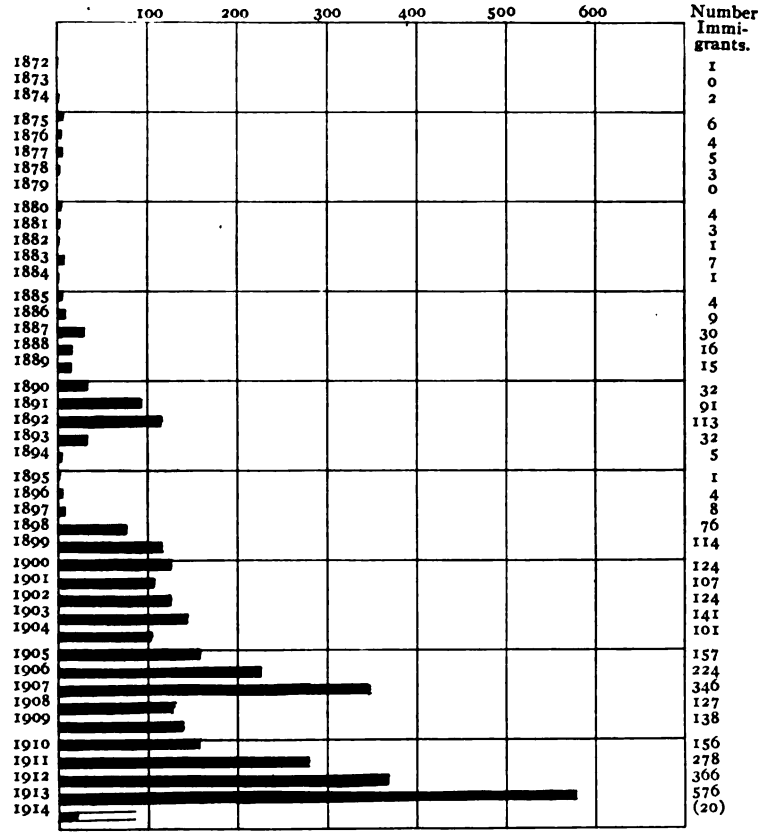
CHART I. Date of Immigration to America of Russian Germans Living in Lincoln, April, 1914



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have seen, there is still a small representation of the earliest Russian German immigrants who came to the United States in the seventies. A larger number and a greater proportion of those who came the following decade also reside in the city. The great majority of the foreign-born population, however, are comparative newcomers. Their date of arrival distributed according to five-year periods, shows the proportion of the total Russian-born Germans in Lincoln to be as follows:

	Per Cent
Before 1899	12.1
1899–1903	17.4
1904–1908	27.3
1909–1913	43.2

Thus, nearly one half of the Russian German immigrants in Lincoln have arrived in the United States within the last five years indicated, while almost three fourths of them have lived in America less than ten years.

A further analysis according to the date of arrival shows that Russian German immigration, like all similar movements, has its ebb and flow; and thus far each incoming wave has risen higher than the preceding. During the initial period of immigration before the nineties, the largest number (30) came in the year 1887. In the following decade, the year 1892 was the crest of the wave and brought 113; in 1903, 141; in 1907, 346; and in 1913, 576. Each of these high tides is preceded and followed by an increasing number of immigrants, and represents not the growth of a single year but of a period.

This brief survey of the composition of the Russian German population of Lincoln discloses the fact that these immigrants are a homogeneous group from the German colonies of the Volga, yet having individual characteristics developed through isolated life in their respective villages during a century and a half. While these people theoretically belong to the "new" immigration of south Europe, their length of residence in America has been sufficient to produce a large number of native-born, with even a few of the second generation, in whom the possibilities for assimilation may be observed. The majority of the Russian

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Germans come assisted by relatives or friends, the proportion being twice as great as for the United States as a whole. The settlements include a large number of new arrivals, almost one half having come within a recent five-year period. The history of their immigration shows that they respond to the same ebb and flow as does immigration in general, although the causes in the two instances are not identical.

II. *Location of the Settlements*

The Russian Germans in Lincoln are settled chiefly along the entire west edge of the city, in two compact groups, separated from each other and from the rest of the city by the railroad yards and the wholesale district. The north settlement extends from Seventh to Fourteenth streets and from the railway tracks to the city limits, occupying a triangular district, the half of seven blocks square. The south settlement is scattered over more territory, running from M to A streets and from Eighth street to the city limits, approximately ten blocks. On the border of each of these settlements and scattered throughout the city is an increasingly large number of Russian Germans who have left their former homes, sometimes in order to be nearer their places of occupation but primarily as an evidence of their rise in the social scale.

The locality occupied by these two settlements is the most undesirable part of town. The west edge of the city dips down into the Salt flats, a wide valley through which a large creek of the same name flows. Two smaller streams which drain a wide territory enter Salt Creek within this basin.[11] The land on these flats is most unlovely to look upon. During dry weather, mineral deposits, chiefly alkali, appear on the surface and explain the absence of trees and of almost all vegetation except coarse weeds. During wet weather, the lack of drainage in much of the settlement area makes the streets almost impassable; while prolonged periods of rain or sudden melting of the snows pour

[11] See U. S. Geological Survey, *Nebraska, Lincoln Sheet,* ed. September, 1897, reprinted November, 1909.

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immense volumes of water down into the basin and turn the several individual streams into one great lake a mile or more broad.

It was this tendency to floods which soon drove the earliest inhabitants of Lincoln back to the high ground on the east and gradually resigned the west side of the city to the railway and wholesale districts.[12] The houses and stores they had built were then occupied by the various foreign nationalities which first came to Lincoln, chiefly Empire Germans and Bohemians, and by the poorer class of American laborers. When the Russian Germans began coming in the seventies, they naturally settled among those speaking their own tongue, and formed a nucleus about which later immigrants gathered. From the nineties on, when the Russian Germans began to form a noticeable part of the community, they gradually preëmpted more and more of this territory until today few families of other nationalities reside within its limits. With the growth of the railroad and wholesale districts, the two settlements became more and more cut off from each other so that now they form two distinct communities.

The location and segregation of this group of foreigners have led the municipal authorities to exclude this part of the city from all plans for improvement. As soon as the settlements became sufficiently homogeneous to differentiate them, the newspaper reporters dubbed them "Russiatown," "Little Russia," or "Little St. Petersburg" and "Little Moscow"; and the community

[12] The first heavy flood after the settlement on the present site of Lincoln was made, occurred in 1869. Again a disastrous flood took place in 1874, when the water rose two inches higher than five years before. In 1878, 1881, 1883, 1891, and 1892 the whole valley was inundated. In 1893 the creek was straightened, and it was hoped the defect was remedied; but another series of wet years proved as disastrous as before. In 1902, 1903, 1907, and 1908 the same experience was repeated. The flood of 1908 was one of the worst ever known and is a landmark in the history of the Russian German settlements. Aside from great property loss entailed, five persons were drowned by the overturning of a boat, four being children of one family. Other effects of this flood will be referred to frequently.

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abandoned them to their own interests. For years the city dumped its garbage into the front yards of the south settlement, and when a protest finally arose it philanthropically transferred its refuse to the back yards of the north settlement. The word "dump" is a common one in the vocabulary of every Russian German child in the settlements. To those on the south side, it signifies a long high ridge partially overgrown with grass, forming a vantage ground on which to play, and sometimes yielding up rich treasures in the form of marbles, broken bits of pottery or brass, and discarded articles of small furniture.[13] To the child in the north settlement it means richer discoveries, for the dump has not yet been picked over; but it also means sickening odors when the breeze drives the smell of decaying garbage into his home, particularly if the wind changes while the dump is being "burned." A little kindergartner, when asked by his teacher to draw a picture of his front yard, covered an otherwise fairly clean sheet of paper with a great black spot and called it the "dump." This conception represents the growing conviction of a large part of the community that our system of garbage disposal is a great blot on a moderately clean and well-ordered city.

For many years a sewer discharged its contents into a natural depression on the edge of the south settlement, although at present it is the policy of the city to extend all such pipes to the creek. These "sinks" now furnish skating ponds for the children in winter, and in summer breeding places for amoebae and other zoological specimens over which dignified professors stoop gingerly, hurriedly gather their prey, and hasten back to their laboratories. For many years, also, the city discharged its human sewage in the same vicinity, and until 1909 the red-light district cut off the south settlement from the business portion of the city.[14]

[13] Just recently several new "dumps" for rubbish alone have been started on the edges of the south settlement. For a number of years an effort has been made to get the city to adopt scientific measures to handle the garbage problem, and in May, 1915, a bond issue of fifty thousand dollars was voted for the establishment of a garbage disposal plant, but a year has passed without anything definite being accomplished.

[14] In 1909 the county attorney enforced the law against these "houses,"

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In spite of the struggle against an adverse environment, the settlements as a whole do not present the characteristics of a slum. Here and there may be found a "foul back street" or a family "of slovenly or vicious type" such as constitute a slum; but these are the rarest exceptions. Order, system, neatness and thrift are the prevailing traits in the Russian German settlements, particularly as regards the buildings. The yards show less favorable results on account of the hopeless battle with the soil and the yet uncontrolled floods. Time and again have small trees and shrubs been uprooted and carried off, and blue grass sod covered inches deep with debris, so that the majority of householders despair of ever getting permanent results. In an attempt to raise the yards above the flood level, many of the people have filled them in with ashes and clay from excavated cellars which can be secured for the mere cost of hauling, and have thus shut off all hope of cultivation. But if the yards lack vegetation they do not lack system and order; and any place filled with junk or rags may safely be set down as not Russian German. A mended though often well-worn sidewalk, scrupulously clean even in the muddiest weather, leads from the street to the house. Fences, porches, houses, outhouses and barns are all neatly and freshly painted. The combination of colors is not always the most fastidious—chrome yellow porches and bright blue houses are conspicuous among the prevailing white of the dwellings and red of the barns—but everything which needs paint is protected by it.

Neglect and decay of buildings is nowhere visible. On the other hand, many of the houses in the settlement are made over from half tumbled-down structures which were bought at a low price, and remodeled under the skillful and painstaking hand of the owner. The Russian German never occupies a house of this sort—unpainted, partly windowless, and dilapidated—and if such are seen in the settlements, the inhabitants will be found to be negroes or the lowest class of American poor.

and since that date segregated vice has not existed in Lincoln. An earlier attempt (1904) made by the city council failed of enforcement by the police. Cf. *Nebraska State Journal,* May 28, 1904.

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In the matter of streets the city has not set the Russian Germans a deserving example; and whatever is praiseworthy here is due to the people themselves and not to any municipal aid. Sidewalk construction in Lincoln is in the hands of the property owners; and long, straight stretches of concrete walks in many places in the settlements show the results of community action among the foreign people. The construction of sidewalks along other almost impassable spaces is held up by a few unprogressive property owners whom the city might coerce if the people had any confidence in their ability to secure action from the officials. But the authorities have not done even their plain duty, let alone helping the people to do theirs. Viaduct approaches and street crossings have been neglected month after month, until some teacher or other influential citizen who had to use that highway sent in a complaint and got the necessary walks. Ungraded streets and undrained pools remain untouched year in and year out as mute evidence of careless and neglectful municipal control.

The two settlements demonstrate the exclusive character of the Russian Germans not merely in the fact that they segregate themselves from the rest of the city, but in their distribution within the settlements. It will be seen at a glance how largely the people

TABLE II. DISTRIBUTION OF RUSSIAN GERMANS WITHIN NORTH AND SOUTH SETTLEMENTS, BY PRINCIPAL "COLONIES"[15]

"Colonies" Having 50 or More Native Citizens in Lincoln					
	North	South		North	South
Balzer	20	308	Kolb	2	62
Beideck	6	256	Kukkus	223	7
Dietel	43	13	Laub	90	3
Frank	4	343	Norka	385	133
Franker Chutor	0	58	Schilling	1	151
Huck	225	12	Walter	3	176
Kauz	73	6	Warenburg	7	70

are grouped in Lincoln according to their native villages, the few exceptions to this rule being in nearly all instances cases of intermarriage.[16] This local heterogeneity of the settlements is

[15] The term "colony" has been the official name, in Russia, for these German villages, and the inhabitants have been known as "colonists."

[16] Incidentally this shows how little intermarriage there has been.

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Types of Houses in the Lincoln Settlements

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preserved in the colloquial speech of the people, who speak of the north settlement as the "Norker bottom" and the south settlement as the "Franker bottom" and who denominate the various churches not by their confessional names of Lutheran, Reformed, or Congregational but as the "Kukkus," "Balzer," "Norker," "Beideck," or "Franker" churches. Again within the settlements the people from each village live in groups, and whole streets will be occupied by former residents of one colony, and other streets by those from another colony. This is especially true of the new immigrants, although not confined to them.

III. *Dwellings and Families*

Housing conditions among the Russian Germans in the settlements present some distinct contrasts to those in the rest of the city. They are neither as bad as in the poorer sections nor as good as those of American people in the same financial circumstances. Ordinarily the dwellings are small, because the people economize in fuel, and consider extra or unnecessary rooms a useless waste. The average house is a one-family dwelling of three or four rooms located on a twenty-five or thirty-five foot lot. A very few large houses have been built to accommodate undivided families such as exist in the village communities in Russia; but the rapidity with which the family in America dissolves and leaves such houses a financial loss, has fortunately discouraged their erection. Some of the few which have been built have been divided into two or three parts and sold to be remodeled into small residences.

The following table shows the number of rooms per dwelling for the houses within the settlements. Since the size of the houses varies materially in the two sections the figures are given for both districts.[17] The four-room house is the most popular in the north settlement, with the five-room dwelling but little ahead in the south. Of the houses in the north side, 23.7 per cent., or almost one fourth, are two room dwellings while in the south side, but

[17] The Russian German population living in Lincoln outside the two settlements is not considered in the study of housing conditions because the people conform entirely to the American communities in which they live.

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TABLE III. NUMBER OF ROOMS PER DWELLING OF HOUSES WITHIN THE SETTLEMENTS

Number of Rooms	North	South	Total
Summer kitchens:			
1	18	.....	18
2	13	2	15
Dwellings:			
1	....	1	1
2	75	42	117
3	60	117	177
4	105	123	228
5	50	137	187
6	30	47	77
7	10	26	36
8	6	15	21
9	2	7	9
10	3	2	5
Total number of rooms	1,390	2,284	3,674
Total number of dwellings	372	519	891
Average number of rooms per dwelling	3.7	4.4	4.1

8.5 per cent. are of this size. The "summer kitchens" are differentiated from dwellings of the same size because they always indicate two houses on a lot and mean more crowding than the single dwellings.

The "summer kitchen" is a distinctively Russian German institution. It is a separate building, of one large or two small rooms, situated a few feet from the kitchen door of the main dwelling. In the German colonies in Russia, this structure was the chief means of protection against fire, which proves so destructive among thatched roofs. In summer, when the buildings were not protected by snow, no fires were allowed built in the main dwelling but all cooking had to be done in these "Sommerkuechen," which must be located as far as possible from the other buildings of the yard and must be constructed of brick or stone.[18] The custom has been transferred to this country although the occasion for it is removed. The buildings are used in summer, as formerly, for cooking and eating and the main dwelling is thus kept cooler and more free from flies. In winter they are usually rented out to returned "beetfielders" or to new immigrants, and the profit accruing from these structures makes

[18] Klaus, *Unsere Kolonien*, Appendix, 35.

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Examples of Summer Kitchens in the Lincoln Settlements

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them very popular in the more restricted area of the north side.

It is a tribute to the Russian German population that, without the guidance of housing laws, they have built the sort of dwelling which now so largely exists in their settlements. Happily, their tendency to homeownership has freed them from the landlord who, desiring to get the most revenue out of his investments, crowds many families under one roof and creates our tenement problem. With their settlements located on the edge of the city, they have been able to expand countrywards; and instead of adapting themselves to discarded buildings such as immigrants in the cities must crowd into, each family has built for itself a house to suit its own simple needs. Although they have paid for inferior vacant lots prices far beyond their value, the communities have suffered less from this exploitation of real estate agents than they would have suffered had they subjected themselves to landlordism.[19] It is a matter of deep regret that the most unsanitary and overcrowded houses in the settlements are the few owned and rented by Lincoln capitalists.

The desire of the Russian German for homeownership is a practically universal characteristic and accounts largely for the generally good housing conditions among them. It gives them a definite purpose in economizing; it encourages them in caring for property, keeping it repaired, and making permanent improvements; and it protects the family life by preserving its privacy, individuality, and pride. The extent to which the Russian Germans own their homes, either free or mortgaged, appears from the following table:

[19] The early history of the settlements in Lincoln favored this individual initiative. Many acres of land adjoining the settlements in pioneer days belonged to the state or to the railway companies, and the immigrants who came during the hard times of the nineties, when there was little sale or use for such land, "squatted" on it and, undisturbed by the owners, put up small houses in which they lived until they were able to buy a lot and build again. In one corner of the north settlement even an unused street was preëmpted and until quite recently several small houses occupied the middle of it.

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TABLE IV. PROPRIETORSHIP OF HOMES

	Residence in America More than 5 Years		Residence in America Less than 5 Years	
	Number	Per Cent.	Number	Per Cent.
Total heads of families	696	100.00	359	100.00
Homes owned:				
Free	422	60.8	31	8.7
Mortgaged	96	13.7	40	11.1
Homes rented	178	25.5	288	80.2

Three fourths of those who have been in America five years or longer own their homes either free or mortgaged; while one fifth of those who have lived in the country less than that period are home owners. A mortgaged home is more often a sign of advancing social position than it is of careless financiering; and it is in these homes where sometimes overwork and neglect of the family are most evident, on account of the strenuous efforts made to pay off the debt occasioned by the move into a better neighborhood.[20] Some of the families living in rented homes are young married people who prefer living alone to sharing the parental roof. In these cases, the head of the family worked until his marriage for his father; and, as is customary, turned all his earnings over to the parents, so that when he came to set up his own home he had nothing to start on. A few of the native-born heads of families and some of those who have lived in America a generation show no tendency toward home ownership.

In so far as the single family dwelling is indicative of good housing conditions, the Russian German settlements are most commendable. There are factors, however, which, though temporary in themselves, are constantly present; and which offer a real problem to a semi-rural community which ought to be entirely free from a tenement population. Overcrowding in the settlements and unsanitary conditions are the chief of these

[20] A larger percentage of families own their homes free and a smaller number, mortgaged, in the north settlement where the dwellings are smaller and the people less ambitious socially than on the south side. The proportions are as follows: North settlement—homes free, 69 per cent.; mortgaged, 10 per cent. South settlement—homes free, 56 per cent.; mortgaged, 14 per cent.

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factors. Although figures cannot adequately represent the former, because it depends upon so many different elements, it is worth while to see what they show and then to supplement that information with specific examples. The lack of a proper standard of comparison such as would be furnished by a corresponding study of the native laboring element of Lincoln reduces the value of the following statistics, which can be compared only with totals for the city at large.

Overcrowding varies greatly in different parts of the two settlements, some streets being no more thickly populated than the average residence portion of the city while other blocks have more than twice the normal number of inhabitants. The density of population also varies with the seasons and with the waves of immigration. During the winter when the people are in from the beetfields, conditions are much aggravated; as they are also when new immigrants come who are sheltered temporarily with relatives or who occupy summer kitchens or rooms in other houses until they can afford to rent a separate establishment. In 1914, when the census of the Russian Germans was taken, there were many of the latter class in the settlements, so that overcrowding was greater than usual. Every possible nook and cranny was packed with people, as is evidenced by the fact that several families of newcomers had to rent places just beyond the border of the settlement. Overcrowding varies with the length of residence in America, being almost always confined to the raw immigrants. A family of eight who came to Lincoln in 1907 and occupied a two-room house the first three years of their residence there, now live in an eight-room dwelling but complain of "being too crowded."

The number of persons per dwelling in the Russian German settlements in 1914 was 6.0 as compared with 4.6 for the city at large.[21] Since the latter figure counts hotels, boarding houses, and apartments each as one dwelling, it would reduce the proportion for the residence section of Lincoln, and intensify the comparison between it and the foreign settlements. Whether the persons are largely adults or children, how many families they represent, and the size of the dwellings they occupy are vital

[21] *Thirteenth Census of the United States*, 1910, Abstract, 262.

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factors in judging the social significance of these figures. We have seen that the average number of rooms in each dwelling was 4.1, thus making the average number of persons per room 1.4.[22] There are no census figures covering this point, hence the reader must appeal to his own experience for a standard of comparison. In the north settlement, which is compactly built up, there is an average of over 100 persons to the block. On the south side no similar estimate can be made because the people are scattered in groups over a wide territory, with few blocks entirely occupied.

The large proportion of children and the few boarders in the settlements, facts which will be demonstrated later, reduce the evils of overcrowding. The following specific examples taken at random show the worst extent to which the practice goes.

Dwelling number 7: summer kitchen of one room; one family of six; four children ranging from four months to four years.

Dwelling number 10: two rooms; one family of seven; three daughters aged 16, 17, and 19, and two sons, 15 and 12, respectively.

Dwelling number 16: two rooms; one family of eight; four children from five to twelve years of age; the grandfather and one boarder (a relative whose family is in Russia).

Dwelling number 65: five rooms; two families (brothers) of sixteen persons; one contains five children from four to fifteen years.

Dwelling number 120: nine rooms; five families of twenty people; (1) parents and two small children; (2) widow; (3) parents, three small children and a boarder (single man); (4) parents and two small children; (5) parents and three small children.

Dwelling number 220: four rooms; three families of fourteen persons including eight children under twelve years of age.

Dwelling number 274: three rooms; two families of twelve people: first includes five children from ten months to seven years; second, three children aged 4, 13, and 17, respectively.

Dwelling number 465: two rooms; one family of eight; six children ranging from six months to eleven years.

Dwelling number 596: seven rooms; two families of nineteen people; first includes nine children ranging from two to seventeen years; second includes five children from one to eleven years and a boarder.

Dwelling number 764: four rooms; three families of twelve persons; (1) parents and four small children; (2) husband and wife; (3) parents and two children.

[22] The north side shows an average of 1.6 persons per room as against 1.3 for the south side.

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Dwelling number 815: three rooms; two families of eleven people; first includes three small children, the grandmother and a boarder; the second includes one small child and a boarder.

Dwelling number 1029: four rooms; one family of eleven; five children from four to twelve years; four male boarders.

The evils of overcrowding are both physical and moral, and so far as the people can mitigate them, they are reduced. Ordinarily, the chief physical harm is unsanitariness which arises from lack of cleanliness, of air, of sewage facilities, and of pure water. Of the first, there is no absolute criterion. The housewife who scoured her broomhandle was formerly the standard of this virtue, but it is quite probable that the modern housewife would object to the sparing use of water by which she achieved undeniably good results. The Russian German prides himself on the cleanliness of his housekeeper and the highest compliment he can pay his wife is to attribute to her this characteristic. One of the chief reasons he objects to being called a "Russian" is explained by the common expression which the German colonist contemptuously applies to his enemy, *i. e.*, "as dirty as a Russian."[23] The most overcrowded homes in the settlements show remarkable results produced through order, system, and hard work. Whether the furniture be little or much, it is arranged with care and precision. The bed is the especial pride of the housewife. Piled high with feathers, with immense pillows at the head, and sheets bordered with handmade lace, this article of furniture is the object of scrupulous care. Sunny days find fences and lines filled with bed clothes undergoing their frequent airings.

Saturdays are as sacredly devoted to cleanliness as Sundays are to godliness and no home misses a thorough overhauling.[24] It would be as disgraceful a thing for a woman to neglect scrubbing her house and her children on that day as it would be to have her husband's Sunday shirt buttonless and his boots unblacked. A group of little girls called at their teacher's home one Sunday

[23] In the Lincoln settlements, the phrase is transposed to "as dirty as the Irish," and is a popular one among the children.

[24] It is the custom in the German colonies in Russia for the people to sweep the streets every Saturday in preparation for the following day.

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afternoon and were taken to her kitchen to make some candy. One of them, a ten-year-old, gave one glance as she entered the room, and then in a tone of mingled disgust and triumph remarked, "You didn't scrub yesterday, did you?" Teacher hastened to explain that "Katie" came on Mondays and that she always scrubbed after she washed; and though the explanation was accepted without argument, the child undoubtedly considered that she had "caught" her teacher in a transgression no whit less than some for which the pupil had been chastised.

The Russian German housewife is a persistent and furious scrubber. No mop disgraces her home, and a broom is too valuable an article to be spoiled by this process. Armed with soap and a cloth or brush, she drops upon her knees and vigorously attacks parlor and kitchen oilcloth alike. Even porches, and walks, or "stepping stones" which may replace the latter, are subject to the same process, although in this instance she rises from her knees and assumes a stooping posture possible only to a seasoned athlete as she gradually worms her way down the walk. Her girls and boys are early taught the art of scrubbing, and their constant application to it accounts for the fact that a stranger, walking through the settlements, can invariably pick out the Russian German houses by the looks of the front porch. The cynic will reply, "their front porches ought to be clean, for they are never used," and there is no denying that in the majority of Russian German homes this part of the house bears the same relation to the rest of the dwelling as did the old-fashioned parlor of our grandparents. Except in the rather rare instances where a bell graces the front door, whoever would "enter in" must go to the rear. The reason for this lies, partly, back in the old home in Russia. There the houses are built directly upon the street with only windows in the front. The door is at the side and cannot be reached except by gaining admission to the yard through the large or the small gate. This method of architecture was adopted when the German colonists first went to Russia as a means of protection against the Kirghiz, Kalmucks, and robbers with which the country was so long infested, and it remains unchanged to this day. When the Germans came to

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Dr. J. F. Krueger

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Two Types of Houses in the German Colonies on the Volga, Showing Measures Used for Protection

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America, they adopted the type of buildings prevailing here but retained, though all unconsciously, their ingrained conviction that he who enters in at the front of the house is a "thief and a robber."[25]

The people also show the effect of their former environment in their sparing use of water as a cleansing agent. In the colonies there were the communal sources of water supply as we have in Lincoln, but instead of having the water piped into each house where unlimited quantities were easily available, each householder was obliged to carry from the spring, creek, or river all that was used for household purposes. Under such circumstances, it may be imagined what economies were practiced in its use, and in this respect the Russian scorns his German neighbor. The Slav performs his ablutions from a ewer hung from the ceiling and (according to his interpretation) washes the dirt away from his face, while the Teuton returns a good share of it to its original place by using the water from a basin. Moreover, the Russians are famous bathers and no *isba* is so poor that it does not include a pile of stones for the *mujik's* vapor bath. The German, on the other hand, contents himself with the less primitive but less effective "tub," and the mark of his complete assimilation in America appears when he considers a bathroom a necessity and not a luxury. The tendency of the Russian German to economize in the use of water was shown in an exaggerated but not exactly typical way by the following incident. A kindergarten teacher had threatened for sometime to send home one of her pupils who came to school with a dirty face, and one

[25] The heavy wooden shutters on the windows of the houses shown in the illustration preceding may be seen on many of the dwellings in the Lincoln settlements. In Russia they served primarily as a defense against robbers, and secondarily as a protection against the cold. In Lincoln they are found chiefly on houses owned by "beetfielders" and are used only during the absence of the family in summer to protect window panes from the unerring aim of mischievous boys.

It is interesting to observe that the better of these two houses belongs to a man who spent several years in Lincoln as a section hand. He returned as "a rich man" with two or three thousand dollars and built this house, which is one of the finest in a colony of 12,000 people.

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morning she carried out her threat by taking the lad home. The grandmother was scrubbing the front porch, and she promptly applied the cloth, with which she was scrubbing, to the child's face and produced an effect which the teacher pronounced "satisfactory."

So far as soap and water are concerned, the Russian German home is faultless, but it suffers from the lack of ventilation. The winters in Russia are so severe that every crack and crevice of the houses is closed to shut out the cold and to conserve the heat; and the weather of Nebraska, though milder, is resisted in the same way. Moreover the small size of the houses here discourages ventilation and on account of the risk from drafts, pure air becomes almost as dangerous as bad air. It is an easy thing, where the sleeping apartments are shut off from the rest of the house, to throw them open at night and leave them thus for half the day; but where there are only one or two rooms in the house, the problem becomes more complicated. Again, the people do not feel the need of fresh air.[26] There is the former, almost universal, notion that some especial danger lurks in the night air; and that outdoor air is especially bad for sick people. This tendency to keep the house closed too tightly results in a faint odor attaching to the clothing of the people which is taken by those who do not know them to be a sign of soiled garments or unbathed bodies. This slight odor is often the basis for unwarranted prejudice against an otherwise cleanly people.

These peculiarities of economy in the use of clean water and pure air are the results of environment and quickly improve under changed conditions. The younger element among the immigrants is less superstitious and more susceptible to suggestion. The example of the American homes in which the mothers work, the teaching of the schools, and the better type of houses which the immigrants acquire after a few years in America, all aid in effecting the change. A young miss of fifteen, after hearing a health talk by a woman physician before a club of school girls, declared: "I can't stand to sleep with the windows shut. My

[26] The windows in the houses of the German colonists on the Volga are not made to open.

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stepmother complains that it is too cold in the morning, but I tell her to lie still until I get the house aired out, and I'll do the work."

Sanitary living conditions are not wholly dependent upon interior cleanliness of the homes and upon pure air; for in a city, and especially in overcrowded sections, the problem of sewage and water supply is vital. These, however, will be discussed in a later chapter under the head of health conditions and only the moral effects of overcrowding will be considered here. These depend largely upon the composition of the "families" in the overcrowded districts. A two-room dwelling occupied by eight people is manifestly an example of overcrowding from the sanitary point of view; but its moral effect will differ vastly as to the age, sex, and relationship of the individuals. The evil decreases in proportion as they all belong to one family, and as the age of the children is low or their sex the same. But let them be a combination of two families, brought about by second marriages, with ages differing widely; or a group of single or married male boarders in a family containing girls or young women, and the problem is greatly intensified. Hence an analysis of the composition of these families is necessary to ascertain the moral effects of overcrowding. Reserving the statistical tables for a later use, the two vital facts in this connection are: first, the number of boarders in the settlements is comparatively small; and second, the number of small children is comparatively large.

The small number of boarders is due to the fact that immigration occurs almost wholly by families and that the young unattached persons usually leave the settlement, either for work in other parts of the city, or for other locations. In the north settlement there were only 20 boarders listed in the census of 1914, and in the south settlement, 61.[27] Of these, 16 were married men whose families were in Russia, 42 were single men; and three were women—one divorced and two single. About a third of these were boarding with relatives, usually with a brother. The

[27] It is possible that some of the boarders in the north settlement were not listed, through a mistaken notion that it might affect the taxes of the informant.

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majority were young men in the twenties who came in the recent immigration chiefly to escape military service; and the total number, comparatively small as it is, was much larger than usual. Most of them are boarded singly, although two groups of four, one of three, and six of two each are found. In almost every case they must share the sleeping quarters of some members of the family although in all but six cases separate rooms are possible. As a rule, the families in which these men stay contain only small children, so that the bad moral effects are reduced to a minimum.

With the Russian German, the keeping of boarders is often not so much a matter of choice as it is governed by a dislike of violating the customary rules of hospitality. A woman who lived in a comparatively spacious house bemoaned the unexpected arrival of her husband's nephew—a married man who left his family in Russia and hurriedly came to America to avoid a threatened return to the army. She did not want to board him; he made so much work, for he didn't know how to keep the house clean; but "it would be shame for us not to keep him, for he is our *friend*."

IV. *Distribution by Families*

The organization of the Russian German family in Lincoln shows the transition from the patriarchal to the modern type. Hence, the number of families returned in the census is indicative of neither the undivided nor the divided family, nor does it agree with the number of married couples and of widowed persons with unmarried children. There are many families where married sons live with their parents and where the *housefather* controls the financial affairs of the entire group. There are other families where married brothers dwell together, sharing some of the details of living but with no common financial interests. Finally the modern family composed of parents and unmarried children is largely represented.

The number of families of Russian Germans in Lincoln is as follows:[28]

[28] This includes only those Russian Germans for whom complete data

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	Families	Individuals
North Settlement	425	2,246
South Settlement	631	3,148
Outside the Settlements	132	706
Total	1,188	6,100

The average number of persons per Russian German family is 5.14 compared with 4.2 for the city of London and 4.5 for the United States as a whole.[29] In this respect it approaches more nearly the eighteenth, than the twentieth, century type of family for in 1790 the average size of the white family in the United States was 5.8 persons.[30]

The size of the family as it actually exists in the Russian German settlements, *i. e.*, including all those living in one family group without regard to relationship or lack of it, is shown in the following table:[31]

TABLE V. SIZE OF FAMILIES

Families	Number of Persons Contained in Each Family											
	1	2	3	4	5	6	7	8	9	10	11	12
Number	3	110	161	175	157	163	122	78	41	19	6	1
Per cent	.3	10.6	15.5	16.9	15.2	15.7	11.8	7.5	4	1.8	.6	.1

The four-member family is the most largely represented, closely followed by the six-, three-, and five-member groups. Compared with the same type of family for the United States as a whole,[32] a significant difference appears in the very small number of

was secured. There are about 400 persons besides these, not here represented.

[29] *Thirteenth Census of the United States,* 1910, Abstract with supplement for Nebraska, 259, 262. These comparisons must be used cautiously, since the bases are not always the same.

[30] See Rossiter, "The Significance of the Decreasing Proportion of Children," in *Annals of the American Academy of Political and Social Science,* XXXIV, No. 1, 71–80.

[31] These figures are based only on the families within the settlement area where conditions are typically Russian German.

[32] The statistics for the United States are found in Mayo-Smith, *Statistics and Sociology,* 186.

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TABLE VI. COMPARATIVE SIZE OF FAMILIES AMONG RUSSIAN GERMANS AND IN THE UNITED STATES AS A WHOLE

	Russian German	United States
1-member family	.30	3.63
2- 6-member family	73.90	73.33
7–10-member family	25.10	20.97
11–12-member family	.70	2.07

persons among the Russian Germans living alone. This fact is indicative of their strong tendency toward family life. The widowed remarry, often at an advanced age; or, otherwise, if their children are grown, they make their homes with them. The comparatively small number of families of eleven members and over is also significant. The figures for the United States are based largely upon boarding houses and hotels where all those living under one roof are classed as a family. In the immigrant quarters of the large cities or in foreign districts like the anthracite coal communities in Pennsylvania, these statistics indicate crowded and unwholesome conditions, where many boarders are housed in small quarters. The few families of this size among the Russian Germans demonstrates the fact already mentioned, that considering the size of the immigrant group, the number of boarders is small, and the evils arising from their presence is at a minimum. The percentage of two-to-six-member families is practically the same for the Russian Germans as for the United States as a whole. The percentage of families consisting of from seven to ten members is considerably larger among the Russian Germans and this is the true index of the comparative size of natural families in the two groups.

V. *Distribution According to Age, Sex, and Conjugal Condition*

The resolving of a population into these factors is a necessary prelude to the explanation of certain social phenomena which that particular group exhibits. For example, a high death rate may be due to the unsanitary conditions under which a people live, or it may be largely explained by the fact that a great proportion of the population is of the age when the expectancy of death is greatest, *i. e.*, under one year or over fifty. Again, criminality

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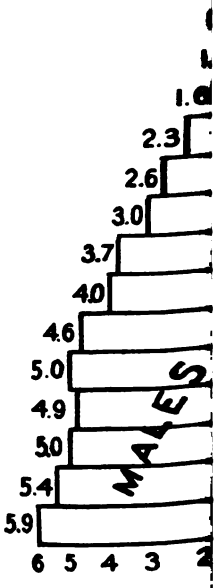

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depends partly upon the comparative number of males and females in a community, and partly upon the percentage of males of the criminal age. Illegitimacy, or the lack of it, depends upon the number of single persons of marriageable age, as well as upon the social customs and ideals of the groups. These factors must all be kept in mind in any discussion of social conditions among the Russian Germans, for upon them depend largely the test of the morality or the immorality, of the desirableness or the undesirableness, of the group.

The distribution of the Russian German population of Lincoln according to age periods is shown in Chart II.[33]

The most striking thing is the abnormally large proportion of persons in the lower age groups: 22.1 per cent. under five years of age among the Russian Germans as compared with 9.9 per cent. for the city of Lincoln and 11.6 per cent. for the United States. The local charts show increases in the middle age periods, the total city population being swollen most largely by young people (20–24 years of age) who come from the rural districts either to enter industry or to attend school, and the Russian German population being most largely increased by immigrants (25–35 years of age) who come here direct from Russia. The small proportion of Russian Germans above sixty years of age indicates the comparative recency of the immigration and the fact that few old people emigrate from Russia.[34] The small proportion of young people from 15 to 25 is striking, and somewhat difficult to account for. The smaller number of males in these groups is due to the *Wanderlust* of youth which leads a large number of young men to leave their father's house, usually without parental consent, and seek adventure or labor elsewhere.

[33] Incidentally this chart illustrates the principle of the stability of large numbers and the instability of small. The figure for the United States shows a gradual decline, while the variations of the other two are neither uniform nor gradual.

[34] The top of the pyramid for Lincoln cannot be completed because the census of 1910 gives only broad-age periods above 40 years. The group from 40–49 years was resolved into two five-year periods on the basis of proportions given in the census of 1900, but no further estimate was possible.

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Some enter the navy, one or two have found their way to the Philippines, while many have stopped on the Pacific coast where they may have relatives or friends. Rarely does one become a "hobo"; sometimes their hard experiences bring them back home subdued and sobered; but more often they set up independent establishments and remain away permanently. Some of the steadiest and most ambitious young men in the community have sought release from home restraints and old-fashioned ideas and customs of family life in this way.

A further comparison by broad-age groups shows some interesting facts. The abnormally large proportion of children under

TABLE VII. AGE GROUPS, BY PERCENTAGES

	0–14 Years	15–39	40–59	60 and Over
Russian German, Lincoln, 1914	48.0	37.7	11.3	2.2
Total, Lincoln, 1910	26.1	45.4	20.2	8.2
Foreign white stock,[35] United States, 1910	21.5	46.4	23.0	8.1
Total, United States, 1910	32.1	43.2	17.8	6.6

fifteen years of age among the Russian Germans is indicative of the high birth rate prevailing among them and of immigration by families at the period of life when fecundity is the greatest. The much smaller percentage of foreign white stock in this lower age group is accounted for by the fact that so many of the other foreign-born groups are adults without their families; and, although the fecundity of all immigrant mothers is very high, the combination of the two elements reduces the proportion of children.[36] The large percentage of Russian Germans in the lower age group implies (1) a high infant mortality; (2) a heavy burden upon the community in providing educational facilities, and a great opportunity in "training up the child in the way he should go"; and (3) a heavy burden upon the immigrant in providing for so large a proportion of non-producers within his group.

[35] Foreign white stock includes those born abroad and native-born having one or both parents born abroad.

[36] Only 5.7 per cent. of the foreign-born are under fifteen years of age, while 38.0 per cent. of the native-born of foreign parentage are under fifteen.

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The distribution of the Russian Germans according to sex shows a normal, stable population. Males comprise 51.0 per cent., and females 49.0 per cent., of the total number of persons. This comparatively equal proportion of the sexes is another evidence of the family character of this immigration. The few married males who are from Russia without their families, and a small number of young men from the rural districts attending school in Lincoln, account in part for the slight excess of males. The city as a whole shows 49.7 per cent. males and 50.3 per cent. females, an excess of females in every age period from ten to forty-five.

The comparatively equal proportion of the sexes among the Russian Germans insures the establishment of homes and the normal increase of this element of the population through birth. It tends to retard assimilation by checking intermarriage, but this is well for both the immigrant and the community because a too sudden change cannot be other than superficial. On the other hand, it permits early marriages to which the people have been accustomed, and lessens impure living and criminality which might otherwise result.

The tendency to establish homes, encouraged by the favorable age and sex distribution of the Russian German population, is shown by an analysis of their conjugal condition.[37] The Russian German males show a larger percentage of single persons over fifteen than do the females, while the latter exceed in each of the other three divisions. While normally about one half a population is married, the Russian German males show 76.3 per cent. and the females 80.0 per cent. The smaller proportion of males among the widowed (1.2 males as compared with 4.0 females) shows the universal fact of their greater tendency to remarry; as does also the smaller percentage of divorced males. When the comparison is extended to the other groups in the table, it shows in every item the greater tendency of the Russian German to marry, to remarry, and to stay married.

[37] The statistics for Lincoln and for the United States are taken from the *Thirteenth Census of the United States*, 1910, 599, 149.

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TABLE VIII. CONJUGAL CONDITION OF THE POPULATION OVER FIFTEEN YEARS, BY PERCENTAGES[38]

Males

	Total	Single	Married	Widowed	Divorced
Russian German, 1914	100.0	22.3	76.3	1.2	.2
Lincoln, 1910	100.0	37.5	57.3	3.7	.5
United States, 1910:					
Total	100.0	38.7	55.8	4.5	.5
Native white of foreign parents	100.0	50.2	46.3	2.8	.4
Foreign born	100.0	31.8	62.1	5.4	.3

Females

Russian German, 1914	100.0	15.6	80.0	4.0	.4
Lincoln, 1910	100.0	31.9	56.9	10.3	.9
United States, 1910:					
Total	100.0	29.7	58.9	10.6	.6
Native white of foreign parents	100.0	41.7	51.1	6.5	.5
Foreign born	100.0	18.3	66.5	14.7	.3

An analysis of the conjugal condition according to ages further reveals certain social facts. To a very large extent, the females marry earlier than the males and both marry before the age of twenty-five. Out of a total of 1,635 males over 15 years of age,

TABLE IX. CONJUGAL CONDITION OF RUSSIAN GERMAN POPULATION ACCORDING TO SEX AND AGE PERIODS, BY NUMBERS

Age	Single		Married		Widowed		Divorced	
	Male	Female	Male	Female	Male	Female	Male	Female
15–19 years	211	196	1	25	..	1	1	1
20–24 years	111	36	108	193	..	..	1	..
25–29 years	31	3	282	316	2	..	..	..
30–34 years	6	1	244	182	..	1	..	1
35–39 years	4	1	183	161	2	1	..	2
40–44 years	1	1	125	100	..	1	1	1
45–49 years	..	..	94	81	1	1	..	..
50–54 years	1	..	88	67	2	6	..	..
55–59 years	..	..	62	52	1	9	..	..
60–64 years	..	..	28	22	5	13	..	..
65–69 years	..	..	19	16	1	8	..	..
70 and over	..	..	13	5	6	19	..	..

[38] The totals in the United States census figures include a small percentage of persons not listed in the accompanying table, whose marital condition was unknown.

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only 43 were single at the age of twenty-five, and out of a total of 1,523 females in the same age group, only 6 were unmarried at twenty-five.[39] The largest number of married persons is between the ages of 25 and 35, at the most prolific period of life for rearing children. By far the largest number of widowed persons is beyond the age of fifty, and it is significant that out of 60 widows, 56 are past the age of child bearing. The smaller number of divorced males does not signify especially that the Russian German women are more addicted to separation than the men, but often the woman remains in the settlement while the man hides himself in an up-town boarding house or in some other locality. Sometimes he has deserted the wife, either before or after leaving Russia, and is thus unrecorded here.

The influence of the conjugal condition of the Russian German upon crime, suicide, insanity, illegitimacy, and the adult death-rate, all of which are decreased among the married, is difficult to determine accurately; but its influence upon the increase of the population is clearly evident. Every condition among the Russian Germans in the Lincoln settlements is favorable to a high birth rate, even higher than in their former home in Russia. The population contains fewer persons in the upper age groups beyond the child-rearing period because the old people do not emigrate. It is more healthy as a whole because the process of selection necessary for entrance into the United States eliminates the physically unfit. It contains many raw immigrants, because Lincoln is a distributing point for this group who come here direct from Russia, and therefore shows the primitive tendency of the foreigner toward large families. Finally the abnormally large proportion of young married people, showing the universal tendency toward marriage and the early age at which it occurs, and the long duration of married life due to few divorces and constant remarriage, produce ideal conditions for a high birth rate.

[39] Something less than a dozen of the forty-three single males are university students living outside Lincoln, and hence not an integral part of the city population.

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CHAPTER II

Birth and Death, Marriage and Divorce

I. *Vital Statistics in Nebraska*

Vital statistics are in such a chaotic condition in the majority of the United States that there is no adequate or reliable basis for a study of the phenomena they present. The following results obtained from the records available must be accepted as approximate and not final, and the excuse for presenting them at all is that they are the only ones which exist, that they are fairly approximate, as any one knows who is familiar with conditions in the foreign settlements in Lincoln, and that they may form a basis for comparison when more accurate work is made available by the state. It is unfortunate that there is no means of checking the results here tabulated; for the Russian Germans are never separated from the other groups and unless one is familiar with the family names of these immigrants he cannot sort out the data relating to them.[1]

Nebraska's tardy recognition of the value of vital statistics and the spasmodic and imperfect enforcement of the laws relating to it are typical of the American attitude toward this subject. There is some comfort, but no help, in the fact that our backwardness in this regard has been due to two factors, the absence of which none of us regret; viz., a state church and compulsory military service. Our system of representation gave us the federal decennial census, the original purpose of which was purely political. As the social horizon has broadened, the social value of the census has become more and more pronounced; and an increasing demand has come for a continuous registration, by the

[1] The writer's interest in laying a foundation for future historical work for this people has led to her copying in almost all instances the data upon which the figures herein contained are based.

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smaller units, of the facts which go to make up what is aptly called "vital statistics."[2,3]

Nebraska has proceeded with the ordinary leisure of the unconcerned in securing the registration of such data. There has not been lack of law, but lack of public sentiment behind the law to secure its enforcement. Marriage was naturally the first event to require registration and these records were not so completely ignored; for every one recognized the state's jurisdiction and control over this institution, the conduct of which was carefully detailed in the statutes. But not so with births and deaths. The congregate growth of the population through immigration was jealously guarded and widely advertised, but its genetic increase and its decrease passed unnoticed.

A Nebraska law of February 12, 1865, provided that the county commissioners require the assessors to make a full and complete return annually of all births and deaths of the preceding year.[4]

[2] In the United States Census of 1900 the only states in which the registration record was accepted as accurate were Massachusetts, Connecticut, Rhode Island, New Hampshire, with certain counties and cities of New York and New Jersey. Bailey, *Modern Social Conditions,* 8. In 1910 the registration area included the New England States, Pennsylvania, and Michigan and the cities of New York and Washington, D. C. "Birth Registration, an Aid in Protecting the Lives and Rights of Children," United States Department of Labor, Children's Bureau, *Monograph,* number 1, 16.

[3] "While the United States led the world with respect to the census of population, we still rank with the most unprogressive and semi-civilized countries as concerns the registration of births and deaths." C. L. Wilbur, "The Census and the Public Health Movement," in *Annals of the American Academy of Political and Social Science,* XXXVII, number 2, 45.

[4] *Complete Session Laws of Nebraska,* I, 430–432. The statute made elaborate provision for the return of these records. Upon blanks provided them the assessors were to make tables showing the age periods of the population, the sex of those born, with the number of plural and still births, and the cause of death, tabulated by months and by age, with sex in each case. The nativity of each person was also to be recorded, as were all cases of idiocy and insanity. The annual returns were to be made to the county clerk on the third Monday of April. Although this would not now be considered a model law because it did not provide continuous and prompt registration of births and deaths, and because it did not throw the responsibility upon the householder or his physician, yet its

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That the law was not being observed is suggested by an amendment passed in 1875 requiring the assessors to take oath as to the correctness of their returns and providing a certain sum per capita for the names registered.[5] The effort to secure vital statistics was finally given up in 1885 when the statute was repealed by an act providing for a state census to be taken that year.[6] For twenty years this law for the registration of vital statistics was on the statute books; but diligent inquiry fails to reveal any results which ever came from it, except a deep regret that it was not enforced.

In 1889 the city of Lincoln passed an ordinance requiring the registration of births and deaths, and since September of that year fairly complete death certificates have been returned because permits were necessary to secure burial in the city cemeteries. Moreover, the town was becoming large enough that the coroner felt called to insist upon this formality as a means of detecting crime. A few birth certificates are found for that year but the health officer failed to enforce the law and for ten years thereafter not a single birth entry is made. In 1901, influenced by a general agitation over the country for registration, the health officer made a spasmodic attempt to enforce the ordinance but only those physicians obeyed who believed in the desirability and necessity of such records.[7] The most faithful person to report was a woman doctor who handled many of the lying-in cases in the Russian German settlements, but almost fifty per cent. of these were treated by Russian German midwives who paid no attention to the ordinance and who were left unmolested.[8] Besides being incomplete, the birth records up to 1912 are unusable for comparative purposes unless the rural records are separated from the city records. To do this, a knowledge of the changes in the city

enforcement would have provided a mine of historical and social data for present use.

[5] *Complete Session Laws of Nebraska,* II, 848.

[6] *Laws of Nebraska,* 1885, 97–108.

[7] In 1903 Congress passed a resolution urging the states to enact suitable registration laws. Cf. *Congressional Record,* 57th Cong., 2d Sess., XXXVI, 585.

[8] Cf. *below,* 47, footnote 14.

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limits at various periods of the municipality's history is necessary.[9]

In 1905, the Nebraska Legislature passed a model Vital Statistics law which was first properly put into effect in Lincoln upon the reorganization of its Board of Health in 1912.[10] There are now on record, therefore, three years of fairly accurate and fairly complete birth and death certificates for the city, although there would have been nine if the law had been promptly enforced. The state, however, is still included (1914) in the list of commonwealths where "good birth registration laws have been enacted—although their enforcement does not yet meet the census requirements."[11] In 1909 the State Registrar of Vital Statistics was made the depositary of data on marriage and divorce, to whom annual reports are to be made by the county judge and Clerk of the District Court respectively.[12] This law has resulted in no more complete statistics in Lancaster County than were available before. Elaborate blanks containing between thirty and forty items are provided, but only such items are filled in as the marriage license or the petition for divorce happen to record. The divorce statistics are woefully deficient, not more than half the items being filled out, because attorneys have not been in the habit of including many of the points asked for, and the clerk's office has not taken the trouble to secure the information from the litigants.

[9] These corrections have been made in the figures used for the tables which follow.

[10] *Laws of Nebraska,* 1905, 466–471. The salient features of this act are (1) that the registration area covers the entire state, (2) that the birth and death certificates are made out according to the standard blanks adopted by the United States Census Bureau, (3) that all local registrars must make a report to the State Registrar, who makes a permanent record of the certificate, and (4) physicians and undertakers failing to report births and deaths are subject to a fine of $10 to $100, or to sixty days imprisonment, or to both.

[11] "Birth Registration, an Aid in Protecting the Lives and Rights of Children," United States Department of Labor, Children's Bureau, *Monograph,* number 1, 16. See also map of the United States on page 2, showing adequacy and inadequacy of birth registration laws in the various states. The Bureau of the Census, however, included the cities of Omaha and Lincoln in its registration area in 1911. Department of Commerce and Labor, Bureau of the Census, *Mortality Statistics,* 1911, 10.

[12] *Laws of Nebraska,* 1909, 347.

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The question of the comparative number of divorces among the foreign-born and the native-born is interesting and important; but the nativity of the client is never recorded, and unless one knows the family names of foreign groups, there is no possible way of distinguishing.

No apology is made for this lengthy and somewhat tedious digression from the point at issue. Satisfactory studies of local, state, or national social conditions can never be forthcoming so long as our records are so carelessly and inadequately kept. "Sound vital statistics are the necessary basis of modern sanitation and register clearly the steps in the campaign against preventable diseases, often pointing the way to the next step. They furnish a definite measure of the value of sanitary improvements."[18] Moreover, it is a fact that the state's confidence is continually imposed upon, as any cursory examination of the records will show. Birth statistics are the most unreliable of all the unreliable vital statistics we have; yet the state fixes a legal age for school attendance, child labor, marriage, militia duty, and the suffrage and provides no way for unerringly establishing it. For example, a marriage certificate dated July 14, 1911, gave a bride's age as 18. A death certificate for this same woman August 8, 1912, gave her age as 16 years 9 months and 18 days. According to the latter and probably correct data, her age at marriage was 15 years 8 months and 23 days, or 3 months and 7 days below the age of parental consent in Nebraska. A young couple went from Lincoln to Council Bluffs and the marriage license issued to them gave the groom's age as 21. A year later he sued for divorce on the ground of fraud in forcing him to marry, and gave his age at that time as 20 years. A young man married in December, 1914, gave his age as 21, although in April of that year the census recorded him as 18. Misrepresentation by those desiring citizenship papers was not uncommon before the new naturalization law of 1906, especially in states which permitted alien suffrage; for where five years' residence was not re-

[18] Chaddock, "Sources of Information upon the Public Health Movement," in *Annals of the American Academy of Political and Social Science*, XXXVII, number 2, *The Public Health Movement*, 305.

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Neighbors

An Average Family

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quired, crowds of voters could be rounded up on short notice and the age of those ineligible could be conveniently stretched to suit the occasion. The care taken under the new law to establish the exact age of the applicant now results in a number of denials of citizenship on the ground that the declarant was under 21 years of age. Misrepresentation of age to school authorities is the most flagrant abuse locally and the Russian German is the chief sinner, not because he is primarily dishonest, but because the state through its neglect aids him in evading a law with which he is not in sympathy.

II. *Birth Rates*

It has been previously pointed out that every condition among the Russian Germans in Lincoln is favorable to a high birth rate. Although comprising less than one seventh of the total population of the city, the proportion of Russian German births to the total number of births in the city was 25.2 per cent. in 1912; 29.7 per cent. in 1913; and 32.3 per cent. in 1914.[14] The phenomenon of a decreasing native population of native parentage in a community where the foreigner is a comparatively recent comer is here demonstrated. The increase from one fourth to one third the total births does not mean that the birth rate among the Russian Germans is rising at that ratio but that the Russian German population increased more rapidly, through immigration, during these years than did the population of the city as a whole.

[14] *Birth Records of the City of Lincoln.* The degree to which the public health reports are deficient is shown by a comparison of the number of births recorded at the health office and the number of christenings in the various Russian German churches:

Year	Health Records	Church Christenings	Year	Health Records	Church Christenings
1902	46	134	1909	168	273
1903	61	168	1910	236	304
1904	63	188	1911	264	327
1905	76	198	1912	291	339
1906	99	220	1913	336	358
1907	139	291	1914	390	382
1908	150	278	Total...	2,319	3,460

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Another measure of the natural increase of population is the crude birth rate; *i. e.*, the number of births per annum per 1,000 of the total population.

TABLE X. BIRTHS PER 1,000 TOTAL POPULATION[15]

Russian German,	1914	60.0
Russian German,	1910	60.8
Lincoln (total),	1910	25.1
Russia,	1910	44.2
Germany,	1910	30.5

The figures however do not show the actual fecundity of marriage among the Russian Germans because there is not the same proportion of women from 15 to 45 years among the Russian German and the city populations; nor is there the same proportion of married persons in the two groups. For example, 28 per cent. of the total population of Lincoln is composed of women between 15 and 45 years, while only 20 per cent. of the Russian German population are women of that age group.[16] Based upon the number of women between 15 and 45 years, the birth rate for the Russian Germans was 318.6 births per 1,000 and for the city of Lincoln 73.2 per 1,000. A similar comparison of the fecundity of marriage between native-born and foreign-born women in Michigan for the five-year period, 1890–1894, shows 111 births per 1,000 native, and 232 births per 1,000 foreign, women.[17]

[15] The data for 1914 are based upon the writer's census of the Russian Germans in that year. The Russian German population in 1910 is estimated from the United States Census as 5,000. The number of births is taken from the total christenings of the eight Russian German churches, which record 304 births in 1910 as compared with 236 registered at the health office. The former would not include a few births where families belong to other churches nor the still births. Moreover, it might include some born outside the city, viz., in the beetfields, but these would be only a few. These facts illustrate, however, the impossibility of ascertaining an absolutely correct rate. The data for Lincoln are based on the United States Census for 1910 and the city health records, which latter are incomplete and make the rate somewhat lower than it should be. For Russia and Germany, see *Statesman's Year Book*, 1912, 1914.

[16] Cf. *Chart II. Distribution by Age Periods and Sex Groups*, 36.

[17] Newsholme, *The Elements of Vital Statistics*, 65.

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This enormous difference in Lincoln is due partly to the large number of unmarried women between these ages in the city at large and the small number among the Russian Germans. An unusually large proportion of single women in the schools, colleges, and university; the usual number of rural immigrants in business and industry; and the increasing number of women of leisure who delay marriage, reduce the proportion of married women between 15 and 45 years in the city to 54.7 per cent., while 80.0 per cent. of the Russian German women of this age are married.[18] Based upon the number of married women between 15 and 45 years, the birth rate for the Russian Germans is 399.1 births per 1,000 and for Lincoln at large, 134.1 per 1,000.[19] Unfortunately there is no way of separating the city rate which all the way through includes the Russian German and does not anywhere show comparative ratios between this foreign group and the native-born, nor between them and the rest of the city.

The potential size of the Russian German family may be ascertained by a study of the number of children born in those families in which the mother has passed the age of child-bearing. Out of 265 Russian German families in Lincoln in which the mother was 45 years and over, the following number of children had been born:

0 children in 18 families;	8 children in 26 families;
1 child in 3 families;	9 children in 37 families;
2 children in 9 families;	10 children in 40 families;
3 children in 4 families;	11 children in 32 families;
4 children in 8 families;	12 children in 16 families;
5 children in 12 families;	13 children in 10 families;
6 children in 21 families;	14 children in 5 families;
7 children in 21 families;	15 children in 3 families.

In 80 per cent. of these families, six or more children were

[18] Cf. *Table VIII, Conjugal Condition of the Population Over Fifteen Years, by Percentages, above,* 40.

[19] In the three years 1890–1892 the annual birth-rate for England was 264 per 1,000 wives. Newsholme, *The Elements of Vital Statistics,* 64.

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born, and in 40 per cent. of the families, from ten to fifteen children.[20] The average number of births was 8.0 per family.[21]

The percentage of sterility among these 265 women was 6.8. The only rate with which this figure can be compared is that given in a study of the population of Massachusetts where, among married women from 50 to 59 years of age, 14.8 per cent. of the native-born were without children, and 9.3 per cent. of the foreign-born.[22]

In these same 265 families, the number of children living was as follows:

0 children in 19 families;	7 children in 27 families;
1 child in 16 families;	8 children in 23 families;
2 children in 20 families;	9 children in 11 families;
3 children in 29 families;	10 children in 2 families;
4 children in 46 families;	11 children in 2 families;
5 children in 37 families;	12 children in 1 family.
6 children in 32 families;	

According to this method of reckoning, there was an average of 4.7 children per family, or 6.6 persons as compared with 5.03 persons in the whole settlements. While in 80 per cent. of these families, six or more children had been born, in only 37 per cent. are six or more children living; and while in 40 per cent. ten or more had been born, in only 1.9 per cent. were ten or more living. In 34 families, 12 or more children had been born but in only one

[20] In one instance a man of 34 married a girl of 14, and in twenty-five years she bore him eleven children, of whom eight are living.

[21] The average number of children in the normal American family at the present time is slightly above two. See Ripley, "Race Progress and Immigration," in *Annals of the American Academy of Political and Social Science,* XXXIV, number 1, 135. In Russia in 1896 the number of births to ten marriages was 65 or 6.5 children per marriage. *New International Encyclopedia,* IX, 804. Tables showing the number of children born per marriage are given for various countries and groups of population in Newsholme, *The Elements of Vital Statistics,* 64–70. However, the method of computation is not known and hence the figures cannot be compared safely with those given above. Cf. also "The Fecundity of Immigrant Women," in *Reports of Immigration Commission,* XXVIII, 731–826.

[22] Kuczynski, "The Fecundity of the Native and Foreign Born Population in Massachusetts," *Quarterly Journal of Economics,* XVI, 158.

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family were 12 children living. There was a decrease through death of 3.3 children per family, or 41.2 per cent. of all who had been born.

The Russian German follows the European trend in natality, and in his birth rate and his marriage rate he is more an eighteenth century product of Germany than of any modern conditions. Thrown out upon the frontier of Europe a century and a half ago, like all pioneers, a part of his service was to multiply and replenish the steppes, and his German ancestry fitted him admirably for this task. In spite of border warfare, epidemics, famine, and slight emigration the population of the German colonies in less than a century showed ten times its original number.[23] They actually increased more rapidly than the native population because they were more protected, particularly from military service, which meant not merely the loss of individual men but of homes as well.

The birth rate, however, among the German colonists in Russia is not so high as it is for Russia as a whole, nor so high as it is among their immigrants in Lincoln. For five years (1907 to 1911 inclusive) the birth rate per 1,000 of the total population of Russia was 44.5.[24] The crude rate for the Protestant German colonies was 40.9 births per 1,000 in 1908 and 36.9 in 1912.[25] The latter shows the effect of three years' famine and emigration. According to this computation, the crude birth rate of the German colonists in Lincoln is about 20 more per 1,000 population than in Russia. This phenomenon of a higher crude birth rate among immigrants in America than in their native home finds a parallel among the inhabitants of the anthracite coal communities of Pennsylvania. These are mostly Slavs from Austria and Hungary where the birth rate is 38.6 and 44.0 respectively per 1,000 population. In Pennsylvania, in five parishes the birth rate was estimated at from 50.00 to 73.33 per 1,000.[26]

[23] Bauer, *Geschichte der deutschen Ansiedler an der Wolga*, 76.

[24] *Statesman's Year Book*, 1914.

[25] Computed from data in the *Friedensboten Kalender*, 1910 and 1914, printed in Talowka, *Government* Saratow, Russia.

[26] Roberts, *Anthracite Coal Communities*, 69–70.

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The Russian Germans—men, women, and children—think in terms of large families. The man's idea of playing "eine grosse Rolle" in state or church is to rear at least as many children as did his father or grandfather. A woman of thirty-two was asked how many children she had and her reply was, "Only six, yet." A girl of fourteen explained her lack of appetite at a table where only two persons were seated by saying that she never could eat unless there were lots of folks around, and quoted one of her countrymen—a physician—who said that it gave one an appetite to eat where there were a great many children.

The American family—or lack of it—is a source of deep mystery to the Russian Germans. They pity the women with no children, for they cannot conceive of such a state occurring from free choice instead of necessity. They suspect the woman with but one or two children, and are convinced that some illegitimate means must be used to accomplish such an end. They are encouraged in this belief by the fact that young girls among them who have left the path of virtue have no difficulty in finding physicians to provide them with unlawful means of escape from their dilemma.

Statistics are too inadequate, and the immigrants' length of residence in America is too short, to note accurately any change in the birth-rate due to other than superficial causes. But through personal acquaintanceship with the people, one detects here and there the beginning of a changed attitude toward the large family. One of the primary causes is the rise in the standard of living, and the consequent feeling that it is impossible to rear so many children properly when the cost of mere necessities is so great. Therefore, "the rich people are the ones who ought to raise children for they can take care of them." The religious objection to a voluntary reduction in the size of the family is met with the conviction that life is a serious proposition and that the calamities which may befall children make it "better if they do not live."

A growing regard for women is also responsible for some of this change. There are not a few young wives in the settlements who have had their health impaired by hard work when they

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came, as young girls, to America a decade or more ago; and either the warning of physicians or the considerateness of their husbands results in a material decrease in the size of their families. The criminal means of prevention found among so many of the younger generation of women of foreign-born parents is not in evidence among the Russian Germans, except occasionally in cases of illegitimate relations. As pointed out later, almost without exception the Russian German girls drop out of organized industry when they marry, and this removes one of the greatest temptations which exists to interfere with the course of nature.

Different ideals of family life will also tend to reduce the birth rate among the Russian Germans in Lincoln. Everywhere in Europe, particularly under the village system of Russia, the child is looked upon as an economic asset. Among the German colonists, the girl, if necessary, takes her place beside the male workers in the field during the summer, substituting for her brothers when they are drafted for military service; while through the leisure season she is the chief factor in the industries which are carried on in the home. On the other hand, every boy born means an added *dusch* to the family income, for each housefather receives as many shares as there are males in his household. Where the shares are so small as they are at the present time among the German colonists, every added one is of especial value, and the death of male children is particularly mourned because it represents a very definite economic loss. In America the child is still considered an economic asset, but the demands of the state for its education reduce its value far below what it would otherwise be. Moreover, while it is customary for Russian German children, so long as they remain in the home, to turn over all their wages to their parents, the law in America absolves them from the necessity of it after they have attained their majority, and very often they avail themselves of the privilege of the law.

More important still is the disintegration of the family which occurs in this country. A very definite thought in the rearing of children is the idea that they will repay the trouble they have cost by caring for the parents in their old age. In America, however, the economic organization of society is not such as to insure them

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this care, and often ungrateful children abuse their unaccustomed liberty by deserting their parents or leaving them to live alone. This is one of the especial grievances which the older people have against America, and which keeps some of them from joining their children here. When, therefore, the child comes to be considered an economic liability instead of an asset, and when he ceases to serve the purposes of an old age pension, the size of the family will automatically decrease.

Sex relations among the Russian Germans as revealed by the statistics of illegitimacy are remarkably pure, the ratio of illegitimate to each 100 births in the Protestant colonies on the Volga being an average of 1.4 for the years 1906, 1907 and 1908.[27] The rates for the European countries are unusually high and for the United States, very low. In 1890, Russia, which ranked among the lowest, had 3.1 illegitimate births out of each 100 births.[28] In 1886–1890, the illegitimate births ranged from 14.7 per 100 for Austria to 3.1 for Holland, with Germany showing 9.3 and Great Britain 4.8. On the other hand, Rhode Island in 1901 had 1.3 illegitimate per 100 total births, and in Connecticut, the rate was 1.1.[29] It is true that the statistics on this subject are difficult to interpret. The temptation to conceal these births is as great as, or greater than, the carelessness in reporting other births. Moreover, with the growth of medical science and the unrestrained practices of vicious doctors, criminal prevention plays a part unsuspected by the public and all too large. Where custom and law demand the immediate marriage of the guilty parties, the real conditions are concealed in the statistics which report all children born in wedlock as legitimate. But the comparative standards of Americans and Europeans, as shown in the statistics, are borne out by travelers who find a vast difference among people of every stratum of society—peasants, middle classes, university students, and social leaders.

The purity of the Russian German family life as shown by the low percentage of illegitimacy may be accounted for partially by the

[27] *Friedensboten Kalender,* 1908, 130; 1909, 131; 1910, 131.
[28] *New International Encyclopedia,* IX, 804.
[29] Bailey, *Modern Social Conditions,* 121.

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low marriage age, the universality of marriage, and the great importance attaching to the wedding ceremony in the simple lives of the people. The impossibility of concealing their shame in the small villages in which they live is a deterrent, as is shown by the fact that in Saratow, a city of 200,000 population, where some 12,000 German colonists live, the number of illegitimate births per 100 among the latter was 5.8 in 1906; 7.6 in 1908; and 5.3 in 1912.[80] In the villages, public opinion is a most powerful preventive. Since marriage in Russia is an exclusively ecclesiastical institution, the minister must be appealed to for the ceremony; and if he learns of the indiscretion of the pair the bridal wreath is torn from the bride and their disgrace is heralded by their being denied a public wedding. The difficulty or impossibility of desertion by the father due to the lack of freedom of travel in Russia and the consequent necessity of being provided with a domestic passport by which he can easily be traced, is a restraining influence. The fact that illegitimacy would stand as a bar to marriage, in a community where the arrangements are largely in the hands of parents and the personal wishes of the contracting parties count for little, would also have its subtle influence.

As usual the woman is the chief sufferer and if she chance to be deserted or conceals her paramour, her lot becomes almost unendurable.[81] Not only is she shunned and despised by her associates, but she is jeered and howled at by the boys of the street, who constitute themselves the guardians of virtue, as much to their own debasement as to the edification of the accused. This custom is transferred to America and prevails in the settlements in Lincoln. A sixteen-year-old girl who had fallen victim to vice through the public dance hall was being accompanied to her home in the settlement on Sunday afternoon by the probation officer's assistant. On their way they passed through the city

[80] *Friedensboten Kalender,* 1908, 130; 1910, 131; 1914, 142.

[81] A writer in the *Volkszeitung,* a semi-weekly paper published in Saratow, describes the popular conduct toward such women and protests against the leniency shown the male culprit in contrast to the pitiless attitude toward the woman. This is one of the numerous signs that the "woman's movement" is penetrating even one of the most secluded corners of the Russian Empire.

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park where a number of boys were lounging. Recognizing the girl but not knowing who her companion was, the boys began calling after her and followed her for some distance hurling vile epithets at her in the German tongue. For months this girl could not go outside her home without submitting to this same conduct from the boys in the neighborhood. The viaduct which separates the north settlement from the city is a *via dolorosa* to any girl who leaves the path of virtue; for here the boys gather and as she goes back and forth to her work, they taunt and tempt her in truly mediaeval fashion.[82]

How far the absolute parental control of matchmaking enters as a preventive of illegitimacy can only be conjectured, but there can be no question that it sometimes causes illicit relations between young people. Although the Russian law permits the minister to perform the marriage ceremony over the objection of the parents, the dependence of the youth upon their family, due to its patriarchal organization, induces them to find some way of escape without breaking its ties. Several instances are known in Lincoln where parents objected to the choice of their child, and the couple checkmated them, not by elopement, as is customary in America, but by assuming prematurely the privileges of the married state. In one case the parents, upon confession of the young people, prepared the ordinary wedding, and concealed the facts from the minister until afterwards.

Apparently this purity in the sexual relations has been the

[82] One of the most effective methods of punishment among the Russian Germans is "shame." However, since the community must act in the capacity of "hangman," it is a question whether more harm than good does not result from this primitive method of meting out justice, particularly when children are employed. An instance of this sort of punishment is given by a correspondent in the *Dakota Freie Presse,* December 27, 1910. A man and his wife in one of the colonies were caught stealing provisions from a neighbor. The customary legal penalties were imposed upon the man; but the woman was taken to the school grounds where she was made to stand with a link of the stolen sausage around her neck and a little cooking-kettle on her arm, while the school children danced about her in a circle and cried, "Wurst, Wurst," "Kalbas, Kalbas." The woman was then led through the entire village, followed by the children "with ear-splitting cries."

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result of forces without as much as of forces within; for when the people come to America, they succumb in a certain degree to a lower standard because of the removal of restraints. Here it is easy for the young man to "skip out" as soon as trouble overtakes him. In this intention he is seldom hindered, and once in a while an innocent victim is forced by the law, or through fear of it, to pay the price another owed. As a rule, however, marriage results, as is shown by the fact that in fifteen years, only two illegitimate births among Russian German girls have been reported. But in all too many cases a birth record follows too soon after a marriage license. The fact that marriage in America is a civil ceremony and that it can be performed without the guilty subjecting themselves to the searching eye of the minister, furnishes a way of escaping one result of their misdeeds. For this reason there is always suspicion among the Russian Germans attaching to those who resort to the civil authorities for marriage.

One of the worst features in connection with these cases in America is the ease with which they can escape the consequences of their sin by appealing to unscrupulous physicians. Instead of advising immediate marriage, the girl is instructed in the art of murder and if she takes this advice she is quite as effectively disgraced in the eyes of her people as though she had born a child out of wedlock. Moreover, the responsibility of the couple for their misdeeds is so lightly thrown off in this way that instead of being warned for the future, they are made more reckless. It is impossible for the best informed persons to tell exactly how many of such cases occur in the Russian German settlements; for sometimes the true nature of the illness is concealed or, again, imaginative neighbors saddle their suspicions upon an innocent girl. But the fact is that girls are here thrown out into industry and meet temptations of which they have never been warned because their mothers know nothing of them. Naturally, some of them go astray; the larger per cent. of these marry; a few of the remainder hide their shame in our state institution, but more seek release through the aid of unprincipled doctors.

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III. *Death Rates*

We have seen that one third of the total births of the city are of Russian German parentage, although that people constitute but one seventh of the population; that the proportion in the city is gradually increasing; and that the birth rate is abnormally high due to the age distribution of the immigrants and to favorable economic conditions. As usual a high infant mortality accompanies the high birth rate, and presents a much more vital problem to the city because it is one over which society has some direct control.

So far as the crude death rate among the Russian Germans in Lincoln is concerned it is commendably low, being 11.0 deaths per 1,000 of their population in 1914 or, exclusive of still births, 9.5 per 1,000. In 1911, the lowest death rates in the registration states of the United States were 10.5 in Minnesota and 8.9 in Washington.[33] Unfortunately there is no way of accurately finding the death rate of Lincoln in 1914; but estimating the population at 45,000, the death rate would be 12.1 per 1,000.[34] The city has long claimed a low mortality based partly on incomplete returns, although there is every condition locally, such as age distribution, occupation, density of population, climate, and physical and social conditions, to encourage a low rate.

As compared with the rest of the city, the death rate of the Russian Germans varies little from the proportion which they constitute of the whole population. They comprise from 12 to 14 per cent. of the total inhabitants of the city, and in 1912, 14.3 per cent. of the total number of deaths were Russian German; in 1913, 12.3 per cent.; and in 1914, 12.2 per cent.[35] While they do

[33] Bureau of the Census, *Mortality Statistics*, 1911, 12. The death rate for Russia, 1901–1905, was 30.9 per 1,000. *Idem*, 13. In 1912 the death rate for the Volga Protestant colonies was approximately 19 per 1,000. See *Friedensboten Kalender*, 1914.

[34] The crude death rate for the registration area of the United States in 1911 was 14.2 (exclusive of still births). Bureau of the Census, *Mortality Statistics*, 1911, 9.

[35] The effect of the foreign population of a city upon the mortality rates is frequently to raise them; for instance, in Boston the death rate in 1900 was raised 3.14 per 1,000 as the net effect of its foreign population.

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not show any great difference in either the crude death rate or the proportion of total deaths in the city, they do show great differences in the number of deaths according to age distribution. It is to be assumed that where there is a large proportion of children or of old people, the expectancy of death will be greater than where the middle age groups constitute the bulk of the population. In so far, however, as infant mortality, *i. e.*, the death of children under one year of age, or child mortality, *i. e.*, the death of children from one to four years inclusive, occur from preventable causes, the community cannot find much comfort in that general rule.

The following table shows the age distribution of the two populations and the proportion of deaths according to those ages:

TABLE XI. DEATHS AMONG RUSSIAN GERMANS AND IN THE CITY AT LARGE, ACCORDING TO AGE DISTRIBUTION

Age Groups	Percentage of Russian German Population, 1914	Percentage Russian German Deaths			Average	Percentage of Lincoln Population, 1910	Percentage Lincoln Deaths			Average
		1912	1913	1914			1912	1913	1914	
0–1 years.....	4.0	37.2	45.1	61.1	47.8	2.1	21.0	22.9	23.0	22.4
1–4 years.....	17.9	27.9	23.1	23.6	24.9	7.8	7.5	7.4	7.0	7.3
5–19 years.....	33.2	6.9	4.9	2.8	4.9	24.3	8.5	5.9	5.5	6.6
20–49 years.....	37.3	15.1	14.7	7.0	12.2	50.6	25.5	23.9	21.2	23.5
over 50 years	7.6	12.9	12.2	5.5	10.2	15.2	37.5	39.9	43.3	40.2
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

It is unfortunate that the percentages relating to Lincoln cannot be reckoned as to its inhabitants excluding Russian Germans, but the United States census does not furnish the necessary basis. The table shows that, in proportion to the total number of deaths, the largest percentage among the Russian Germans occurs in the lower age groups; and for the city at large, in the upper age groups.[36] For example among the former, the percentage of

Cf. Davis, "The Relation of the Foreign Population to the Mortality Rates of Boston," in *Medical Problems of Immigration,* 51.

[36] The figures upon which these percentages are based include the still births.

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deaths under five years of age was 65.1, 68.2, and 84.7 of the total number respectively for the three years, or an average of 72.7 per cent.; while for the city at large it was 28.5, 30.1, and 30.0, or 29.7 per cent.[37] The proportion of deaths over fifty years of age is much lower for the Russian Germans than for the city at large; while in the middle age groups, where mortality should be the lowest, the rate for the city at large is almost twice the proportions for the immigrants.

These figures are significant only as one keeps in mind the age distribution of the two groups. Of the Russian German population, 21.9 per cent. are under five years of age, while only 9.9 per cent. of the population of the city fall within that age group. On the other hand, the city has many more elderly people than has the Russian German and many of these deaths in the city are of persons over sixty years of age. The age distribution of the Russian Germans is such, then, as to warrant a greater expectancy of death than in the city at large, particularly in the lower age groups.[38] The real question and the one of social significance is whether or not any considerable number of these deaths are preventable.

The large proportion of deaths under one year of age among the Russian Germans argues, at first glance, for a high infant mortality rate; but such is not actually the case. The proportion of infant deaths (exclusive of still births) per 1,000 living births for the three years, 1912–1914, has been as follows:[39]

[37] The infant and child mortality among the Slavs of the Pennsylvania coal fields was 70 per cent. of the total deaths, while the English-speaking children formed 40.7 per cent. of the entire mortality. Roberts, *Anthracite Coal Communities*, 79.

[38] If the figures were available it would be possible to compute the death rates for each age group and thus show exactly the comparison in healthfulness between the two populations. See Bailey, *Modern Social Conditions*, 216–220.

[39] The proportion of still births is also lower for the Russian Germans than for the city at large, being in 1914, 2.8 per 100 for the former and 3.4 for the latter. The same fact was found to be true among the foreign women in Pennsylvania, where 17 to 20 per cent. of the still births were among Slav mothers, and 68 to 80 per cent. among English-speaking mothers. Roberts, *Anthracite Coal Communities*, 81.

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TABLE XII. NUMBER OF DEATHS UNDER ONE YEAR PER 1,000 LIVING BIRTHS FOR LINCOLN AS A WHOLE, FOR LINCOLN EXCLUSIVE OF THE RUSSIAN GERMANS, AND FOR THE RUSSIAN GERMANS, 1912–1914

Year	Lincoln (Total)			Lincoln (Exclusive of Russian Germans)			Russian Germans		
	Number Living Births	Number Infant Deaths	Infant Mortality Rate	Number Living Births	Number Infant Deaths	Infant Mortality Rate	Number Living Births	Number Infant Deaths	Infant Mortality Rate
1912	1,161	85	73.2	822	62	75.4	339	23	67.0
1913	1,110	112	100.9	752	91	121.0	358	29	81.0
1914	1,168	97	83.0	786	61	77.6	382	36	94.2
Average.....			85.7			91.3			80.7

The statistics will be found to differ greatly between the various groups, and also within each group; while the period covered is so limited and the figures are so small, comparatively, that it is difficult to formulate any general rule. Especially is this hazardous because of the incompleteness of the records. One fact, however, is clear and of vital importance: the infant mortality rate among the Russian Germans does not differ vitally from the same rate in the remainder of the city, and the Russian German infant has about the same chance to grow out of babyhood into childhood as does the average child in the city. This fact is particularly significant locally because, for some years, the impression has prevailed in the community that there is an abnormally high infant and child mortality in the Russian German settlements as compared with the city at large. The statistics, however, do not bear out this supposition.

It is true that the community is more conscious of the infant mortality among the immigrants because it is localized; *e. g.,* in 1914, 36 infant deaths out of a total of 97, or almost one third, occurred among the Russian Germans, and most of these were within the settlements.[40] But practically one third of the total number of births occurred among the same people; and naturally, where the births are, there must be the infant mortality, also.

However, it is undoubtedly true that the infant mortality rate

[40] In the discussion of vital statistics, the figures for the Russian Germans include the entire city, and not merely the residents of the two settlements as in the case of housing conditions previously discussed.

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of the entire city is larger than it should be, or than it need be if proper means were taken to reduce it. It is difficult to say just how far this could be done, or what would be a reasonable standard to set. The average rate in Lincoln of 85.7 for three years is certainly not high compared with the estimated rate of 124.0 for the United States as a whole, or with some of the American cities as shown in the following list:[41]

Johnstown, Pa.	55,000	134
Malden, Mass.	44,000	90
Springfield, Ill.	51,000	130
Wichita, Kans.	52,000	102
South Bend, Ind.	53,000	182
Omaha, Nebr.	124,000	126
Grand Rapids, Mich.	112,000	122
Los Angeles, Cal.	319,000	97
Indianapolis, Ind.	233,000	123
Kansas City, Mo.	248,000	154
Seattle, Wash.	237,000	82

But conditions in these places may vary widely from each other and from circumstances in Lincoln. Here there are broad streets, spacious yards, few tenements, and only a small manufacturing population. Every outward encouragement for a low infant mortality exists, and no community is absolved which has any appreciable amount of preventable waste of human life.

In New Zealand, a country whose history and conditions are not unlike some of our western states, remarkable progress has been made in reducing infant mortality from a rate which was comparatively low to begin with. In ten years (1902–1912) the infant mortality rate for the country as a whole was lowered from

[41] For statistics relating to cities of 100,000 population and over, see Bureau of the Census, *Mortality Statistics,* 1911. For the infant mortality rates of Johnstown and Malden see Duke, "Infant Mortality, Results of a Field Study in Johnstown, Pa.," Children's Bureau, *Infant Mortality Series,* No. 3. For the data concerning the remaining cities, chosen on account of similarity in size and conditions to Lincoln, I am indebted to Miss Julia Lathrop, Chief of the Children's Bureau. The figures represent the infant mortality rate for 1908–1912, for which period the rate for Lincoln was 99.8.

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83 per 1,000 births to 51, while the rate for Dunedin, a city the size of Lincoln, declined from 89 to 38 deaths per 1,000 births.[42] The fact that so large a proportion numerically of the infant deaths in Lincoln are in a definite locality and that the causes producing them are fairly uniform makes the matter easier to handle.

The first requisite in solving the problem is a knowledge of the exact causes which result in the death of so many children. This is not an easy thing to find out even in so small a place as Lincoln. So many factors enter into the problem that it becomes an exceedingly complex one in spite of the simple terms to which statistics apparently reduce it.[43] There are a few diseases which account for most of the deaths among infants and children, but the conditions which produce these diseases are greatly varied. They can probably be summed up in the two words "dirt" and "ignorance," but these factors result in things other than infant mortality, and, moreover, they are doubtless the basis of nine tenths of all the diseases to which human flesh is heir. If the specific forms of dirt and ignorance which cause the death of so many children can be discovered it will help in the early solution of the problem. Everywhere at present, statistics show that diarrhoeal diseases are one of the three main causes for infant mortality. The occurrence of these diseases "depends, wholly or partly, upon surrounding temperature and deficiency of rainfall, upon urban and social conditions, and upon pollution of food, chiefly milk, or other articles intimately associated with the life of infants."[44] To combat this one disease is no simple matter. The importance of a pure milk supply has been emphasized and much has been done in the larger cities by way of milk stations,

[42] See "New Zealand Society for the Health of Women and Children, an Example of Methods of Baby-saving Work in Small Towns and Rural Districts," published by the United States Department of Labor, Children's Bureau, *Infant Mortality Series,* number 2, Bureau pub. number 6.

[43] A casual perusal of the addresses at the annual meetings of the American Association for the Study and Prevention of Infant Mortality convinces the layman of the degree of specialization necessary in coping with the problem, and that here also "doctors disagree."

[44] Newman, *Infant Mortality,* 152.

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but artificial feeding is not a factor in the infant mortality of the Russian German settlements in Lincoln, for this practice is almost unknown among these foreign mothers. This reduces the problem of a pure milk supply to a minimum, particularly since many of the people keep their own cows which they pasture on the edge of the settlement, and which supply themselves and their neighbors with fresh milk.[45]

The bad effect of midwifery upon the infant mortality rate is often alleged, and it is true that the Russian Germans employ these women very largely. In 1914, 201 of the 390 births reported among these foreigners were attended by midwives, and only 186 by physicians.[46] According to the health records the work of the midwives is increasing, although this is probably only apparent, due to the fact that they have not been held strictly to account in reporting births until very recently. There are six or eight of these Russian German women, all of whom are untrained and who have no legal or professional standing in the community. Nevertheless the sum total of their work in the foreign settlements redounds to the good, rather than to the harm, of their patients. They are, as a rule, cleanly in their habits, as is evidenced by the fact that puerperal septicaemia practically never results from their work. Besides they do not attend infectious cases as do the regular physicians, who not infrequently transmit infection in this way. They are more patient and careful than the doctors who "treat the people like dogs," in the words of one of the physicians themselves. Their fees are low, averaging from $5 to $8 a case and, in addition to the technical services they perform, they nurse

[45] Several years ago an attempt was made to check the infant mortality in the settlements by the establishment of a pure milk station in the ward school building. During two months' existence only one call was received (and that largely from curiosity) although milk from the University Experiment Station was furnished at less than cost. The plan failed, not because the people were too stubborn, or too ignorant, or too heartless regarding their children to receive the proffered help, but because it did not meet the need in solving their problem.

[46] From 30 to 85 per cent. of the deliveries of infants in large cities are in the hands of these women. Newmayer, "The Warfare against Infant Mortality," in *The Public Health Movement, Annals of the American Academy of Political and Social Science,* XXXVII, number 2, 295.

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the patient and do the work about the house. Of the same speech, sex, and faith as those whom they attend, their services are of much more value to the mothers than are those of the majority of the doctors who commonly practice in the settlements, unless it can be shown that actual harm results from their work. The testimony of competent and sympathetic physicians, of the health authorities, and of the statistics so far as they reveal the facts, does not disclose such results.

It is unfortunate that no attempt is made by the state to recognize the midwives and to raise their status. This cannot be done by passing arbitrary laws shutting them out of practice, for this would do more harm than good by depriving the immigrant of any medical attention except the help volunteered by neighbors. It would also increase the difficulty of securing birth registrations; for the number of Russian German midwives is a practically stable quantity and the authorities can keep an eye on them, while it would be almost impossible to ferret out the unattended births in the settlement. But the state could demand the registration of midwives,[48] it could fix a certain reasonable standard to which all should conform, and it could provide some means of education whereby this useful class of medical attendants might become a positive means of good.[49]

[47] The Russian German midwives employ many customs belonging to the folk medicine of the German villages. For instance, they will not allow the mother to go to sleep, nor will they give her cold water to drink. They wash the new born child's eyes with milk and place a cloth wet with whisky on its head. As a rule, these practices are harmless, based purely on superstition; but the people have much more confidence in their potency than in modern medical science.

[48] See Wile, "Immigration and the Midwife Problem," in *Medical Problems of Immigration*, 119–125, and Schwartz, "Prenatal Care," in *Transactions of the Fourth Annual Meeting of the American Association for the Study and Prevention of Infant Mortality*, 174–190.

[49] Since the above paragraph was written, the Superintendent of Health of the city of Lincoln has taken steps to provide instruction and supervision for the midwives. The women were first called together and the city nurse explained to them in German the purpose of the Health Department to organize a school of instruction for them, with meetings to be held once a month in the North Side Neighborhood House. A series of lec-

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The large size of the families must have its effect upon infant and child mortality, not only by depriving the children of the necessary care, but often by weakening the mother, and indirectly the child, through overproduction. As a rule, however, to counteract these evils, two years intervene between births, and the period of child-bearing is extended over a longer time. It is common to find women past forty who have young babes, and some even past forty-five. Out of 75 Russian German women over forty years of age, 50 had children living who were born since the mothers had reached forty years; while doubtless some had borne children who are now deceased—a fact which the census did not show. Of these 75 women, 7 had given birth to children at forty-four; 3 at forty-five; 3 at forty-six; and one at forty-seven. This prolonged period of child-bearing means that often a woman is a grandmother before all her own children have come; and it means that her whole life, after marriage, is engrossed with children and children's children.

Another factor indirectly increasing infant mortality, and child mortality as well, is the effect of the voyage to America. This would be felt especially in the three years, 1912–1914, on account of the heavy immigration of that period. Of the children of one year of age or under who died in 1912, six were born in Russia or on the way to America; in 1913, four under the age of one, and five between the ages of one and five; and in 1914, three under one, and two under five years of age. The figures do not tell the whole story, however, for not infrequently a Russian German mother buries her baby at sea or in some foreign land where the family was detained at an emigrant station. Not merely the effect of the hardships of the voyage upon the child itself, but the general conditions surrounding the family in its new environment in America would tend to make themselves felt in

tures was provided for them, and meanwhile the office sent to Germany for copies of a standard book on obstetrical work. Each woman bought a copy, and lessons are now assigned which they study and discuss at their regular meetings. The sessions are faithfully attended, intelligent interest is shown, and the midwives without exception express their appreciation of the help being given them.

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an increased death rate. The poverty and overcrowding incident to the life of the raw immigrant and the homesickness and hard work of the mother must necessarily affect her physically and mentally. If figures were available, they would undoubtedly show that infant and child mortality decreases with the length of residence in America, even though the birth rate remains the same for a generation.

The direct causes for death assigned in the death certificates are not always reliable; and moreover, as has been stated, one needs to know the causes for the disease itself before a remedy can be suggested. Frequently the secondary cause of death is the one to be guarded against, *e. g.,* measles seldom prove fatal but pneumonia following measles is a common cause of death in children. The health records for the years 1912 to 1914 inclusive, show the following attributed causes for death among the Russian German children under five years of age:

TABLE XIII. DISTRIBUTION OF DEATHS OF RUSSIAN GERMAN CHILDREN UNDER ONE YEAR OF AGE AND FROM ONE TO FIVE YEARS (EXCLUSIVE), ACCORDING TO PRIMARY CAUSE

Cause of Death	Infant Mortality (Under One Year)			Per Cent. of Total Infant Mortality	Child Mortality (From One to Five Years)			Per Cent. of Total Child Mortality
	1912	1913	1914		1912	1913	1914	
All causes.....	23	29	36	88	24	19	17	60
Respiratory diseases..	6	10	6	25.0	12	6	3	35.0
Diarrhoeal diseases...	4	11	9	27.4	7	5	6	30.0
Congenital debility. Premature birth....	11	4	15	34.0	..	1	1	3.3
Accident.....	..	..	..	0.0	1	1	2	6.7
Other causes (13).....	2	4	6	13.6	4	6	5	25.0

The diseases producing infant mortality fall into three groups, the largest number being due to the perils attending birth, such as prematurity, malformation, inanition, etc., which are largely ante-natal in their origin.[50] Enteritis and pneumonia are the two other principal causes for deaths of babies during the first year. Among children from one to five years, pneumonia demands the

[50] Thirty per cent. of all the infant deaths in England are due to this same cause. Newman, *Infant Mortality,* 62.

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greatest toll, with enteritis closely following, while contagious diseases, chiefly diphtheria, and accidents form an appreciable factor.

It is significant to note that the diseases producing infant mortality in the foreign settlements in Lincoln are in general the same as elsewhere. In Newman's exhaustive study of the subject in England the fatal diseases of infancy are shown to be: wasting diseases, 31 per cent. of the total; diarrhoeal, 21 per cent., and respiratory, 16 per cent.;[51] while in the intensive study made in Johnstown, Pa., by the Children's Bureau, these diseases claimed 27, 26, and 25 per cent. respectively of the total infant mortality.[52] In the Russian German settlements in Lincoln, the proportion for these diseases in the same order as stated is 32.9, 27.2, and 25.0 per cent.[53]

Even after this analysis is made, the core of the matter is not touched; for positive and accurate information can result only from the tracing of each individual case, and intelligent action on the part of the community can come only after such a study has been made for the entire city. It is certain, however, that the causes for infant and child mortality are both social and individual; and that the community has it in its power through sanitation and education to reduce materially the number of such deaths. So far as sanitation is concerned the Russian Germans have done nearly all in their power to improve their living conditions, and no great change can occur until the city gives to the settlements better drainage of streets and alleys and removes the garbage deposits from their midst. How much harm results from water standing in cellars of the homes where there is no drainage, cannot be said; and though it is probably never the direct cause of death, it undoubtedly lowers the vitality of those who live in such

[51] Newman, *Infant Mortality*, 45.

[52] Duke, "Infant Mortality, Results of a Field Study in Johnstown, Pennsylvania, Based on Births in One Calendar Year," 37, in United States Department of Labor, Children's Bureau, *Infant Mortality Series*, number 3, Bureau pub. number 9.

[53] The registration area for the United States shows the same order for the diseases producing infant mortality. Bureau of the Census, *Mortality Statistics*, 1911.

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houses. However cleanly the homes, the people cannot escape the effects of odors from undrained sewage and pools of stagnant water, piles of manure and garbage heaps thrust upon them by the city, nor the more direct effect of well water contaminated by seepage through such polluted soil.

Probably an important cause for infant mortality (and child mortality, as well) over which the individual has control, is lack of protection against cold. The immigrant coming from Russia finds here a climate much milder than the one to which he has been accustomed and underestimates its effect upon the weak. The children are not warmly enough clothed; the houses are not kept sufficiently and evenly heated, while crowded conditions often subject the child to sudden changes of temperature. It is not unusual for mothers to take small babies to the church when the building has not been ventilated or heated and to sit through a long service when the temperature within the house is colder and damper than without. Particularly is this true of week-day services, such as funerals, when there is no one at home with whom to leave the child.

The Russian German mothers, as a rule, are not "grossly inexperienced or negligent in the care of their children." The majority of them spent their childhood caring for babies and the care of children comes second nature to them in spite of their youth at marriage. The young married women seldom go out to work either in organized industry or in the homes, and thus the care of their infants is not shifted upon some one else. The neglect of children is most apt to occur where the family is large and demands the mother's work away from home, and where the care of the younger children falls to the lot of the older ones or possibly to aged or infirm grandparents. Thus, contrary to the general rule, it is usually the later born who suffer neglect more than the first born, and the older babies instead of those under one year of age.

The Russian German mother as a rule is healthy in body and mind, and is contented and happy in rearing her family. Her children are not unwelcomed as is sometimes the case elsewhere, and her interests are usually narrowed down to the individual

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care of them. Her ambition sometimes gets the better of her judgment and sends her out to wash and scrub when the children would be as well off with fewer clothes and more personal care; but this applies more to children who have reached school age, than to the younger ones. The mother's chief failure, as with most mothers, comes through ignorance of elementary but important hygienic principles. The existence of a simple family diet may not save the small child from being fed things that are hurtful and fatal to it. Irregularity of feeding does more harm than unclean or improper foods. The customary dependence on home remedies tempts the family to delay calling medical help until every other means is exhausted, and this often proves too late to save the baby, as is not infrequently noted by the physician on the certificate of death. This attitude of mind results also in the use of patent medicines and liquor which, as a rule, is kept in the home "as a medicine." The general principles of hygiene in its relation to infant welfare are largely an intuition with the Russian German mother. The houses are, as a rule, kept cool in the summer, not because she knows the scientific effect of heat upon infant mortality, but because she has been accustomed to cooking outside. Sometimes where the summer kitchen is lacking, women will be found doing the cooking over an open fire in the yard to save heating the kitchen.

Definite education of the women and girls would undoubtedly accomplish results in a comparatively short time. The raw immigrant mothers could be reached through the midwives if these were properly instructed; while others might be helped through visiting nurses.[54] The girls are being better prepared by the teaching of hygiene in the grade schools, and further specialized instruction is possible through special clubs and other existing organizations. The movement for "Little Mother's Clubs" is good in principle but unfortunate in the name chosen. It is too suggestive of relieving the proper agent of care and of placing responsibility upon those not physically or mentally mature

[54] At present (June, 1915) the city jointly with the Charity Organization Society and the Board of Education employs a visiting nurse who gives a large proportion of her time to work in the settlements.

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enough to bear it. Aside from the definite results to be accomplished through better sanitation and through the education of mothers, whatever tends to improve social conditions in the community will make itself felt in lowering the number of deaths of infants and small children. Education, however, will not be properly effective until the Russian Germans are taught how unnecessary are the deaths of many of their children. They have been accustomed to great epidemics of children's diseases which carry off, in some years, several hundred out of a single colony. No such event has ever happened in this country, and the gradual decrease of the child population as it occurs in Lincoln does not arouse them to any feeling of alarm. Only when they begin to feel that it is not entirely the "divine will" that their children die, but that they have some control over the matter, will they do their fair share in eliminating the preventable waste of child life.

To sum up the question of death rates among the Russian Germans in Lincoln, we have seen that for these people as a whole they are about the same as for the city at large, or somewhat lower. The largest percentage falls upon children under five years of age, but according to the number of births, the infant mortality is a trifle lower for the Russian German than for the whole city. Undoubtedly it might be quickly reduced by ascertaining the definite causes; but better sanitation by the municipal authorities and education through visiting nurses and through the school will tend to the same end, though more slowly.

IV. *Marriage*

It has been pointed out that under the favorable economic and social conditions prevailing in Lincoln, the crude birth rate of the Russian Germans is increased over that which exists in the German colonies in Russia, and that the death rate is decreased. The variance noted in these physical processes of birth and death is still more pronounced in relation to marriage, which responds with greater readiness to outward conditions.

The exact degree of change in the marriage rate cannot be given, but only approximated. From April, 1913, to April, 1914,

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there were seventy marriages among the Russian Germans in Lincoln, giving a rate of 10.7 marriages or 21.4 persons married per 1,000 population. In 1910, there were fifty-four marriages, a rate of 10.8 marriages or 21.6 persons per 1,000.[55] These two rates, while corresponding almost exactly, are the results of entirely different local circumstances. The number of marriages in the first instance was the highest ever reached among the Russian Germans in Lincoln; while in 1910, the number was at the lowest ebb in a nine years' period. Representing, therefore, two entirely different sets of circumstances which yet produce practically the same result, these figures may be taken as the average marriage rate among Russian Germans in the city.

In the Protestant German colonies on the Volga, the marriage rate during a six-year period ranged from 10.6 persons to 15.0 persons per 1,000 of the population. The approximate rates for the various years were as follows:[56]

1906	15.0 persons per 1,000 population
1907	13.2 persons per 1,000 population
1908	13.3 persons per 1,000 population
1912	10.6 persons per 1,000 population

It will be noted that there is less difference between the highest and lowest rate in the colonies than there is between the former and the average rate in Lincoln; and also that the average rate in the city is more than twice the lowest rate in the colonies. Thus, the marriage rate of the Russian Germans rises greatly under the favorable living conditions in Lincoln.

Before discussing the specific causes for this change, it will be profitable to compare this marriage rate with those prevailing in some other countries, and in certain parts of, or groups of population in, the United States.[57]

[55] *Record of Marriage Licenses in Lancaster County, Nebraska.*

[56] Compiled from the *Friedensboten Kalender,* 1908, 1909, 1910, 1914.

[57] The statistics for the European States, except Russia, and for New England are taken from Bailey, *Modern Social Conditions,* 137. For Nebraska and Lancaster County, see Nebraska State Board of Health, *Bulletins,* 1912–1915. Cf. Roberts, *Anthracite Coal Communities,* 60, for

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PERSONS MARRIED PER 1,000 TOTAL POPULATION

Europe:		
Hungary	1900	17.7
Germany	1900	17.0
England and Wales	1900	16.0
Ireland	1900	9.6
Russia	1902–1906	17.8
United States:		
New England	1893–1897	17.5
Nebraska	1910–1913	18.3
Lancaster County	1910–1913	28.6
Anthracite Coal Towns of Pennsylvania	1899–1901	24.0
Russian Germans in Lincoln	1910, 1913	21.5

The marriage rate for the Russian Germans is decidedly in advance of the rates for the European countries or for the United States. The rate for Lancaster county is raised to unusual proportions by out-of-town "trade." The fact that it is the capital city brings many young people here for their marriage ceremony, particularly during the state fair which occurs in the late summer. Hence this rate needs to be refined before it can be used for purposes of comparison.

The fact that two immigrant groups so vastly different as the Slav miners in Pennsylvania and the Russian Germans in Lincoln, Nebraska, present the same phenomenon of an increased marriage rate in the United States, suggests the probability of this being a general law. The marriage rate for Hungary, one of the highest of any of the European States, is 17.7; but the Slavs in Pennsylvania have a rate of 24.0. In the Protestant colonies on the Volga, the marriage rate is about 17.8; while among the Russian Germans in Lincoln, it rises to 21.5.

Various conditions are favorable to this high marriage rate among the Russian Germans in Lincoln. Among the first of these is an equal distribution of the sexes due to their almost universal custom of emigrating by families. The age distribution, on the other hand, is not such as to encourage a high marriage rate, for, as we have noted, a comparatively small number

the data concerning the Slavs. For Russia, see Webb, *New Dictionary of Statistics*, 615.

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of young people are found in the settlements. Therefore, if the marriage rate were to be computed according to the number of single persons of marriageable age, the difference between the Russian Germans and the surrounding population would be much more marked.[58] In spite of the lack of young persons among the foreigners, the almost universal tendency of the widowed to remarry helps to raise the rate to its unusual height.

The economic laws which affect the marriage rate in general in all countries scarcely operate within the Russian German settlements in Lincoln. It is a general principle that "the marriage rate falls in hard times and rises on the recurrence of prosperity."[59] But in so far as it can be computed for this foreign group, it follows the curve of immigration more closely than it does the rise or fall in prosperity, and often quite contrary to it. Hence, the first or second year following each high tide of immigration has always shown an increase in the marriage rate beyond the proportionate increase in population.

The years from 1892 to 1894 inclusive are the first and most striking example of this fact. Up to 1891, as has been previ-

[58] In a comparative study of marriage rates among the native and foreign born in Massachusetts, a vast difference was found between the two, but this was much reduced by comparing the ages of the two populations. Thus, in the years 1887–1889, the marriage rate was as follows:

	Persons per 1,000 Population	Rate Corrected for Age Distribution
Natives	16.6	15.5
Foreign born	30.9	26.9
Entire State	20.5	18.6

The large number of adults and the small number of children among eastern immigrants apparently raises the rate to an enormous figure, which is much reduced by correcting the rate for age distribution. Cf. Kuczynski, "The Fecundity of the Native and Foreign Born Population in Massachusetts," *Quarterly Journal of Economics,* XVI, 1–36, 141–186. A similar correction for the Russian German population in Lincoln, however, would raise the marriage rate instead of lowering it, because the age distribution of the two foreign groups is the direct opposite.

[59] For a summary of the principles governing the movement of the marriage rate, see Howard, *General Sociology, an Analytical Reference Syllabus,* 27; also Mayo-Smith, *Statistics and Sociology,* 93, 100–101; and Bailey, *Modern Social Conditions,* 142–144.

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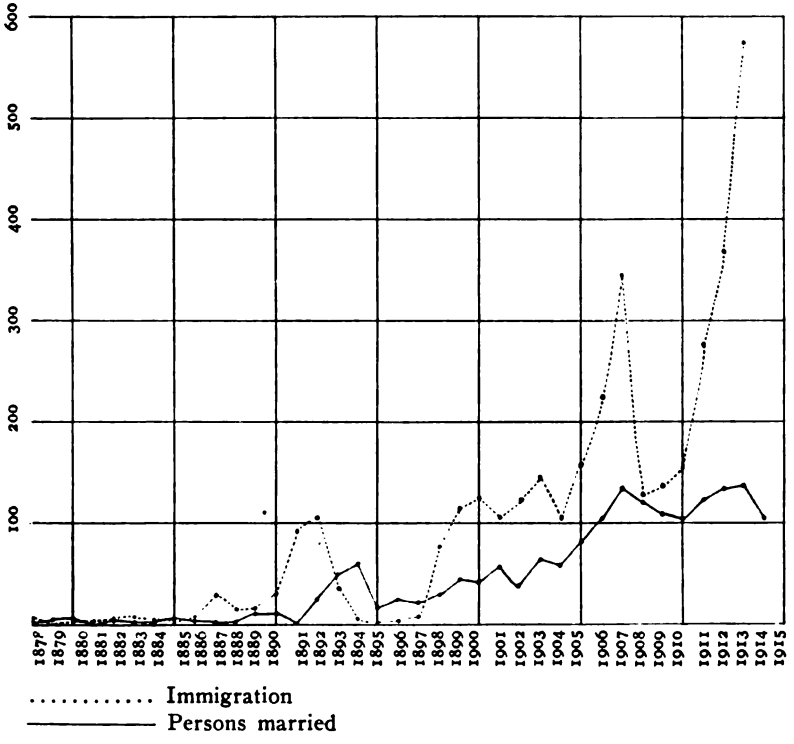
CHART III. Number of Russian Germans Married in Lancaster County, 1878–1914, Compared with Immigration Wave



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ously shown, many of the immigrants were either young, single men who came alone or families containing such youth as would soon be eligible to army service. The excessive number of males of marriageable age in proportion to the Russian German population must result either in mixed alliances or, for the more conservative, in deferring marriage. Meanwhile the immigrants were becoming established in industry and prosperous enough to set up homes of their own. When, therefore, in 1891 and 1892 a large immigration resulted from the famine in Russia, the marriages reached an average of 22 per annum during the years of 1892, 1893, and 1894. At a liberal estimate of 500 for the Russian German population of the city it would mean an annual rate during these "hard times," of 44 marriages or 88 per 1,000 population.[60] Again, the year 1907 was one of financial depression but it followed the heavy immigration of 1906–1907 and registered the largest number (67) of Russian German weddings ever recorded in the county in one calendar year.

The Russian German in Lincoln is less susceptible to the influence of prosperity upon the marriage rate than is the American, because what are considered poor times in America would be good times in Russia. The principle operates most truly when the standard of living is high or when the line between affluence and poverty is so slight that the loss of a crop or two reduces many families from comparative comfort to absolute privation. This latter is what occurs in the German colonies in Russia, where the marriage rate is so keenly sensitive to harvest conditions that newspaper correspondents invariably remark upon the connection between the two facts.[61] The dearth of marriages is also more noticeable there because the period when weddings occur is limited to one season of the year, and greater social prominence is laid upon them. Moreover, there is so little diversification of industry that a poor harvest settles the matter finally for every one. Among the Russian Germans in America, on the other hand, the prospect of a "job" in some of the unskilled avenues

[60] This reminds one of the shipment of maidens to the Virginia colony in the first days of its history.

[61] *Dakota Freie Presse,* February 24, 1914.

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of labor, and the comparative prosperity of the immigrant even in times of financial stress, keep hope alive and encourage them to carry out their plans in spite of temporary conditions. Those who have lived here longer, however, and have a higher standard of living, similar to the American element, are more susceptible to the general principle controlling the marriage rate.[62]

In the age at which they marry, the Russian Germans of Lincoln differ decidedly from the American population. They marry earlier in life; there is less range in the marriage age; and the women of certain classes seem to marry younger in America instead of older as one would expect to find. Of 730 Russian German brides of the first marriage, 60.0 per cent. were married between the ages of 18 and 20, while the ages of all ranged only from 16 to 38.[63] Of 722 Russian German grooms, 59.9 per cent. were married between the ages of 21 and 23, varying from 18 to possibly 40 years. Few persons, either men or women, pass the 25-year line before marriage.[64] Of the above number of brides, 94.2 per cent. were married under 25 years of age, and of the grooms, 88.5 per cent. Distributed among five-year periods, these marriages occurred as follows:

TABLE XIV. AGE AT MARRIAGE AMONG RUSSIAN GERMAN BRIDES AND GROOMS

Age at Marriage	Brides, Per Cent	Grooms, Per Cent
16–20 years	62.7	5.3
21–25 years	33.9	77.8
26–30 years	1.9	12.4
31–35 years	1.1	3.4
36–40 years	.4	1.1

[62] These facts demonstrate the proposition that it is the lack of luxuries which deter people from marriage, but not the lack of necessities.

[63] *Marriage Records of Lancaster County, Nebraska,* IV–XL (1878–1914). The previous marital condition is noted only since 1909 and it is not always possible to tell whether it is a remarriage unless the title "Mrs." is prefixed. With the grooms there is no opportunity to distinguish, except as one knows the facts from other records, hence the figures may be somewhat higher than they should be.

[64] "In Russia the marriages take place much earlier than in any other country on account of the national customs and the peculiar system of

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During the thirty-seven years since their immigration began (1877–1914) the average age for Russian German women was 20.1 years and for the men, 24.9 years. In Massachusetts in 1901 the average age of all brides was 25.8 years and of all grooms 29.2 years.[65]

A change in the marriage age is shown from an analysis of the Russian German weddings of the last twenty years.[66] From

TABLE XV. CHANGE IN MARRIAGE AGE OF RUSSIAN GERMANS IN 1895–1904 AND 1905–1914

Age at Marriage	Brides				Grooms			
	1895–1904		1905–1914		1895–1904		1905–1914	
	Number	Per Cent.	Number	Per Cent.	Number	Per Cent.	Number	Per Cent.
16–20 years	106	61.6	313	65.3	13	7.5	21	4.5
21–25 years	65	38.0	148	30.8	126	73.4	369	78.7
Over 25 years	1	.6	18	3.9	33	19.1	79	16.8

this table it will be seen that more women are marrying at 16–20 years of age than formerly and fewer men; and fewer women are marrying at 21–25 years and more men. The figures for over 25 years are less significant, especially for the men, because it is probable that some of these are remarriages.

The change in the marriage age is accounted for largely by social and economic conditions. With the poorer class of women, the marriage age has fallen; while with the better class, it has

land tenure." Bailey, *Modern Social Conditions,* 153. Of the females, 58 per cent., and of the males, 37.8 per cent., were under the age of twenty years (1872–1880). In Rhode Island for the same period, about 14 per cent. of all persons married were under twenty years of age.

[65] Bailey, *Modern Social Conditions,* 152.

[66] The time covered by the records from 1878 to 1914 falls into three periods: (1) 1878–1891, when there were few Russian German immigrants, and considerable intermarrying because of a disproportion of sexes; (2) 1892–1894, when a large influx of new immigrants raised the marriage rate beyond all normal proportions; and (3) 1895–1914, when an equilibrium of sexes and an ordinary movement of population produced stable conditions.

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risen. Both changes are largely due to industry, and the difference in result depends upon the type of service entered. Girls who go into the unskilled industries are thrown with crowds of other irresponsible girls whose thoughts and conversation are largely confined to the "making of dates." They are thrown with men either in their work or on the streets; and with no interest except their daily monotonous grind, they seek excitement in association with them. Soon beyond the control of parents, they marry early either against the latter's consent or with their reluctant approval.

Aside from these facts, the normal tendency would be for the marriage age to rise, for in the German colonies in Russia the two factors of military service and the patriarchal family system tend to push the age downward. There the young men must go to the army at 21, and they are encouraged to marry early and establish a family before the lots are drawn, for if this is not done, from five to nine years' service delays marriage beyond the desired time.[67] It is the feeling of parents that their sons will be steadier, while away from home, if they are married. Besides, it will be a bar to their contracting alliances while off on garrison duty with Polish, Russian, or other foreign women whom to deceive is cruel; but to marry, involves religious complications. The parents of sons are especially anxious to contract marriages for them. The more well-to-do classes reason that they will have to hire help anyway, and that the son's wife will save money to them and be a financial asset to the son. If a male child is born, it will mean one more *dusch* or land share for the family and thus help to compensate for the economic loss to the family of the recruit. The parents of daughters, on the other hand, would resist this tendency if they could, but since there is no way of telling who will be drawn and since the marriage age is much below 21 years, their wishes in the matter count for little. The patriarchal family system places a premium upon marriage by bringing into the family an extra worker without any expense except board and clothes. The teachings of the church have had

[67] This service is now reduced to three years for the army and five for the navy.

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a potent influence upon the marriage age. Luther taught that "young" marriages were most desirable and recommended from sixteen to eighteen years for girls and seventeen to nineteen years for boys. The Russian Germans have gone little beyond that, since the most of the girls in the colonies marry from seventeen to eighteen and the boys from eighteen to nineteen.

Although the statistics do not clearly show the fact, it is nevertheless true that the marriage age among the Russian German men and women of the higher social class in Lincoln is rising. It invariably ranges from 22 to 25 years of age for the women and often past 30 for the men.[68] This class includes those who go on to the high school and the university, and who defer marriage by reason of the prevailing sentiment of a different environment, or in order to carry out ambitions which have been aroused. The same reasons operate upon those who have learned a trade, as millinery, dressmaking, bookbinding and the like, or upon those who are in business pursuits, as clerking and stenography. Besides, their rise in the social scale narrows their choice of mates, for most of them still prefer to marry within their own nationality (or if not choosing it voluntarily, they respect their parents' wishes in the matter) and the number of Russian Germans who have risen to the same social level is necessarily limited.

The tendency of the parents to discourage marriage becausc the children are considered an economic asset, is probably more enforced with this class than with their inferiors. The higher standard of living which they have adopted demands the income of the children, and the older ones of the family especially are encouraged to share in assisting the parents to meet expenses. Any discussion of the matter is ended by the very apparent proposition that "if you marry so young, how do you ever expect us to get back what you have cost us"?[69]

[68] The American-born children of Russian German parents show the same class difference in marriage age which the foreign-born exhibit. Those who have moved outside the settlement respond to the community influence and delay marriage; while among those who have remained in the settlement, the marriage age has become still lower.

[69] Several instances are known of young men whose fathers, backed by their legal rights, demanded the services of their sons until the latter

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Every people has its "time to marry," and June roses bloom for the Russian German youth in the heart of the winter.[70] In the colonies in Russia the weddings usually begin after the "Kerb," which is the fall holiday celebrating the close of work in the fields and the beginning of the leisure season.[71] It is observed on different dates in the various colonies, during the months of September and October; and is a veritable mating season for the young people. The weddings usually begin the first Tuesday in November and continue until the Advent Season, which opens the fourth Sunday before Christmas.

The favorite time, however, is from the week immediately following Christmas until the beginning of Lent, six weeks before Easter. Economic convenience and ecclesiastical sanction have so crystallized sentiment concerning this marriage season among the German colonists that any breaking away from it is considered a sign of apostasy.[72] In expressing her disapproval of American marriages in general, a pious Russian German woman said "The Americans are like the Russians; they get married just any time."[73]

This marriage season has been observed by the Russian Ger-

were 21 years of age. These young men did not marry until they were 26 or 28 years of age, or until they had worked long enough for themselves to gather sufficient property to marry.

[70] For the marriage season among the Slavs in Pennsylvania, see Roberts, *Anthracite Coal Communities*, 65–66.

[71] This is a survival of an old German custom which was at one time universal and which is still retained in many rural sections of the Empire. Mogk, *Deutsche Sitten und Braeuche*, 11, says: "Wie in alter Zeit finden auch heute noch in vielen laendlichen Gegenden Deutschlands die Hochzeiten im Spaetherbst oder Winter staat. Das ist die Zeit, wo die Jahresarbeit zu ruhen pflegt und die Ernte, die Fruechte der sauern Arbeit, hereingebracht ist."

[72] A wedding in the summer is an unusual occurrence and happens only when the parties are contracting a second marriage or when the ceremony is necessitated by some circumstance, legal or illegal.

[73] As a matter of fact the Russian is more limited than the American in choosing his wedding day, for the festivities may not occur during fast. That eliminates Wednesday and Friday of each week, the Lenten season of seven weeks before Easter, the five weeks following Pentecost, and the three weeks following October 21.

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mans with great regularity since their residence in Lincoln, partly because the annual migration to the beetfields has produced industrial seasons similar to those in the old home. A comparison of periods, however, shows an increasing tendency to conform to American customs, by a more even distribution through the months, with a decidedly growing preference for June.

TABLE XVI. NUMBER OF RUSSIAN GERMAN MARRIAGES BY MONTHS, 1900–1914

	1900	1901	1902	1903	1904	Total	1905	1906	1907	1908	1909	Total	1910	1911	1912	1913	1914	Total	Grand Total
January	4	3	4	7	6	24	4	7	10	14	11	46	6	10	5	5	6	32	102
February	1	6	2	3	2	14	6	11	10	10	9	46	4	8	2	1	4	19	79
March	1	..	1	6	1	9	5	5	4	10	3	27	8	5	3	6	6	28	64
April	1	2	1	1	5	10	3	4	7	8	6	28	1	3	10	10	3	27	65
May	..	..	..	..	2	2	4	3	5	3	2	17	2	3	3	2	2	12	31
June	2	..	3	3	5	13	2	2	4	6	1	15	6	5	11	3	6	31	59
July	1	6	1	2	..	10	1	4	2	1	4	12	3	3	4	6	2	18	40
August	..	2	2	2	2	8	3	2	2	2	1	10	4	6	3	5	4	22	40
September	3	1	1	..	2	7	1	2	5	..	3	11	4	5	4	9	8	30	48
October	..	4	..	1	1	6	2	..	4	2	6	14	5	3	11	4	5	28	48
November	2	3	1	3	3	12	1	2	8	2	5	18	3	5	6	10	5	29	59
December	6	..	3	4	1	14	10	10	6	5	2	33	6	5	3	5	3	22	69

The percentage of marriages occurring in November, December, January, and February has decreased during the three five-year periods from 49.9 per cent. to 48.0 per cent. and 34.2 per cent., respectively, while the proportion and actual number of June marriages have doubled in the last two decades.

This change in the marriage season is an evidence of assimilation, as is also any tendency to intermarriage. The German colonists in Russia have been decidedly endogamous in their alliances, intermarriage being very uncommon except among the highest classes. This is chiefly due to religious differences, and to the fact that according to the Russian law, the issue of mixed marriages must be enrolled in the Orthodox church.[74] So strongly is this principle engrained into their nature that the older

[74] The law of April 16, 1905, gave permission to all persons over eighteen to change their church affiliation. In 1907 the age was raised to twenty-one, but the red tape connected with the process is so great that few take advantage of it and it remains an effective check upon intermarriage.

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people especially manifest decided disapproval of marriages outside their own group.[75] Not infrequently parents bring such pressure upon a young man or woman as to induce them to give up a proposed union with a foreigner. "People ought to marry the same," they say, "then they can raise their children alike," meaning that common religious training is necessary to insure the proper rearing of offspring. Those who are more liberal in their views concerning intermarriage in general, unanimously draw the line at the "Irish"; and since this term to them is synonymous with Catholic, the opposition really rests as before upon a religious basis.

Another and more reasonable ground for opposing mixed marriages is the unfortunate outcome of so many of them. Those of the lower social class in America who contract such alliances almost invariably marry persons who are inferior in character to themselves. Girls who work in hotels or restaurants marry men who are cooks and dishwashers or ticket sellers for cheap theaters. In a year or two, their home is broken up, the American husband deserting his wife and child entirely, or the American woman, as the case may be, frequenting the public dance halls and entertaining "strangers" to the ruin of her husband's purse and the neglect of all her wifely duties. A young girl who married an American dishwasher in the Chinese restaurant where she had worked, and who by her conduct had lost caste in the settlement, thus opened her heart to a pedestrian who helped her wheel her baby across the viaduct, one violently windy Sunday: "I'm going up to the county jail to see my husband. He sent word for me to bring the baby up for him to see. It's now over a year old and he has never seen it, for he left me four months before it was born. I know what he really wants me for, though. He wants me to get him out of jail but I'm not going to. He has left

[75] A correspondent in the *Dakota Freie Presse*, September 10, 1912, writes that one of his townsmen has married a Russian lady who taught in the Zemstvo school in their village and that the marriage ceremony was performed by the Russian priest in Saratow: "Sie ist die erste Russin, welche hier in Kukkus Einzug gehalten hat. Die alten Deutschen schuettelten zwar die Koepfe, aber. . . ."

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me twice now and he can just stay where he is until he gets ready to support me and the baby.[76] O, I felt so *ashamed* when folks asked me where my husband was and I didn't know." Such unfortunate experiences as this have not been infrequent, and the divorce court has played so prominent a part in the intermarriages of the lower class that all such are looked upon with suspicion and doubt. The current opinion upon the subject is expressed by a newspaper correspondent who urges the young people to "marry industriously" but warns the young men "not to remain sitting by an English lady, for with them marriage does not usually last long." The correspondent "knows several good German Russian boys who made that mistake and were separated within three months. That is the way in America, if young folks do not get proper instruction."[77]

The rate of intermarriage has varied greatly during different periods on account of local conditions, but under normal circumstances it is on the increase.

TABLE XVII. NUMBER AND PERCENTAGE OF INTERMARRIAGES BY RUSSIAN GERMANS IN PERIODS FROM 1878 TO 1914

	Marriages	Intermarriages	
		Number	Per Cent.
1878–1891	27	13	48.1
1892–1894	66	8	12.1
1895–1904	198	24	12.1
1905–1914	572	89	15.5
	863	134	15.5

The average number of mixed marriages during the entire period has been 15.5 per cent., varying from 48.1 to 12.1. The extremely high rate during the first period is due to the fact previously mentioned that many of the first immigrants were young single men who had been brought or sent by their families to

[76] The Nebraska law against wife desertion, passed in 1903, provides for imprisonment in the penitentiary for not over one year or in the county jail for not over six months, for a husband who abandons his wife or refuses to support her. *Revised Statutes of Nebraska,* 1913, Secs. 8614–8617.

[77] *Dakota Freie Presse,* January 28, 1913.

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America to keep them from military service. There were few available young women of their own nationality, and this inequality of the sexes led to intermarriage, chiefly with Empire Germans. When the immigration of the nineties provided a supply of women, the percentage of mixed marriages dropped to 12.1. During the last twenty years of more normal conditions, it has risen from 12.1 in the first decade to 15.5 in the second decade—a sign of the growing assimilation of the people.

More Russian German women marry outside their nationality than men, a total of 73 women and 61 men having contracted mixed marriages. The excess of women is the more striking when one recalls that in the first period, nine tenths of the intermarriages were of Russian German men; while in the year 1908, nine tenths were of Russian German women. The occupations which are followed account in part for the greater independence of the men. The foreign women are thrown with native men in industry more than the Russian German men are thrown with native women, and this contact sometimes results, as has been seen, in intermarriage.[78]

The marriage licenses issued in Lancaster county, show the birthplace of those intermarrying Russian Germans to be as follows:

TABLE XVIII. BIRTHPLACE OF THOSE INTERMARRYING WITH RUSSIAN GERMANS, 1878–1914

Birthplace	Brides	Grooms
United States	39	54
Germany	17	16
Hungary	2	1
Denmark	1	
England		1
Italy		1
Russia (Slav)	1	
Unknown	1	
Total	61	73

[78] But in European countries it is also true that native women are much more likely to marry outside their group than are foreign men. Bailey, *Modern Social Conditions,* 165; Mayo-Smith, *Statistics and Sociology,* 111–112.

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Of the foreign-born, Germany has the far greater proportion, but this is partly true because the largest foreign group in Lincoln outside the Russian Germans is the Empire Germans. Some of the native-born are also of German parentage while others are of Irish, English, Scotch, and Bohemian stock. The largest proportion of them, however, are probably American.

The native-born Russian German who has been reared in the settlements in Lincoln shows the same general tendency of the foreign-born to marry within his own nationality; while those who have been reared outside this group, almost without exception contract mixed alliances. Out of 53 native-born Russian German women, 23 married foreign-born Russian Germans, 4 married native-born Russian Germans, and 26 married Americans. The same proportion appears for 34 native-born Russian German men, 12 of whom married foreign-born and 5, native-born Russian Germans, and 17 married Americans. So long, then, as the Russian Germans remain within the settlement, they show only a slight tendency to intermarry, even though they may be American born; but when they move outside their group, they are more and more inclined to mixed marriages, an increasing evidence of their assimilation.

It has been pointed out how little the German colonists in Russia have intermarried, even outside their own village. In view of this endogamy, their attitude toward the marriage of blood relatives is of especial importance. Since marriage is an ecclesiastical institution in Russia, each religious group retains its peculiar customs and laws. For the Greek Orthodox and the German Catholics, the marriage of cousins is forbidden; while the Evangelical Germans permit it.[79] Among the wealthy Protestant colonists, the marriage of cousins-german very often occurs, in order to keep the property within the family or within the same social circle. But popular sentiment among the common people strongly opposes such unions, although the children of stepbrothers or sisters commonly marry.

[79] For a discussion of this subject at various periods and among different peoples, cf. Howard, *A History of Matrimonial Institutions,* index under "Forbidden degrees."

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When the Russian Germans first came to Nebraska, immigrants not infrequently married their cousins in order to avoid the greater calamity of marrying outside their nationality. But relatives always compare the children of these unions with others, and blame any physical defect upon this relationship. However, in spite of a generally strong feeling against consanguineous unions, the marriage of cousins today is a rather common occurrence with the Russian Germans in Lincoln, although since 1905 it is contrary to the law of the state of Nebraska.[80]

These alliances occur among persons of every social class. A young woman of exceptionally good family, native-born, recently wished to marry her cousin, whose brother, a few years previously, had married her sister. The parents refused their consent on the ground of the relationship, but the couple decided to marry in spite of the parents' wishes. It used to be customary, when the Nebraska statute forbade divorced couples to marry within six months, for such persons to evade the law by going to Council Bluffs, Iowa, and getting married at once. Laboring under the impression that the law against consanguineous marriages might be evaded in the same way, this couple took a witness and went to Council Bluffs to have the ceremony performed. But Iowa also forbids such marriages, and since the family names of the contracting parties were identical, the clerk suspected an illegal case and refused a license. However, the parties and their witness swore that they were not related and the clerk finally issued the license and the ceremony was performed.

In another case shortly previous to the one related above, a girl seventeen years old was sent a ticket by an aunt and uncle; and when she arrived from Russia, she was summarily married off to their son, her cousin, the matter of age and relationship both being arbitrarily adjusted to suit the Nebraska law.[81] No objections

[80] *Laws of Nebraska,* 1905, 449; *Compiled Statutes of Nebraska,* 1905, 1058, Chapter 52, section 3.

[81] The age of consent in Nebraska is twenty-one for males and eighteen for females; the age of parental consent is eighteen for males and sixteen for females. Cf. Howard, *A History of Matrimonial Institutions,* II, 471–473.

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have ever been raised to any of these cases, and the people will go on with the practice until it is challenged in the courts.

Remarriage is the almost universal rule among the Russian Germans and the proportion of second marriages (and sometimes third) is very large. As has been seen, few persons are found living alone or unmarried, and the ages of widows on remarriage range from 20 to 60, and of widowers from 24 to 61. Except with young people who marry single persons, remarriage always means the union of two or more families and the rearing of another, so that some excessively large families are formed in this way. Financial considerations do not prove a deterring element in these alliances for one or both of the parties may be very poor. Moreover, it is considered that the large number of children acquired will prove an asset instead of a liability. It is customary in Lincoln for a man to dispose of his dead wife's belongings to the neighbors for a financial consideration, since his new spouse will bring him the same things in her dowry. Some enterprising widowers several years ago saw the possibility of realizing a larger sum from these effects by a Sunday afternoon auction and at the same time providing a social function for their friends. This method of disposal, however, is not general, but is an example of mongrel customs which arise from a combination of American and foreign manners.

V. *Divorce*

Among the German colonists in Russia divorce is an almost unheard-of thing. Although the right of separation exists, the disapproval of public opinion, the authority of religion, and the difficulty and expense connected with securing a divorce make it a rare occurrence. The only ground for it in Russia is the scriptural cause of adultery; and since women are taught to believe that they must submit to their husbands in all things, they are practically denied the right of divorce, though they may have abundant cause for action. Since marriage is an ecclesiastical institution in Russia, divorce must be obtained through the church authorities. The parties must present their case to the pastor,

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who draws up a petition to the Consistory of the Lutheran church (in case they are Protestant Germans). This is then sent to the Holy Synod of the Orthodox church which canvasses the matter and returns its answer through the Lutheran Consistory to the pastor. Local inquiry failed to find anyone who knew exactly by what ceremony or formula a divorce was granted, so unfamiliar are the people with the phenomenon. But tradition says it occurs as follows: the couple appear before the pastor who says to them "God does not divorce; the devil does." He then commands them to join hands as they had done at the wedding ceremony and separates them as a sign of their divorce. The law permits remarriage after a certain period, but public sentiment is so strongly against the divorced woman that it is seldom she can remarry even if she be the innocent party.[82] In their attitude toward divorce, as toward the position of women in the family, the Russian Germans seem to have been influenced by Russian sentiment more than by the lenient attitude of Luther.[83]

The divorce rate based upon the population given in the Census of 1910, was 3.7 per 1,000 the total population for Lancaster county, while the rate for the Russian Germans was .4 per 1,000. The proportion of divorces to the number of marriages can be more accurately stated.

TABLE XIX. NUMBER OF MARRIAGES TO ONE DIVORCE FOR LANCASTER COUNTY AND FOR THE RUSSIAN GERMANS, 1909–1914

Year	Lancaster County	Russian German
1909	3.8	17.6
1910	3.5	26.0
1911	3.5	20.3
1912	3.8	8.1
1913	3.3	13.2
1914	4.6	12.8

[82] Divorce is more rare among the higher classes than among the lower, on account of the stigma attaching to it.

[83] For the Protestant doctrine of divorce which was largely shaped by Luther, cf. Howard, *A History of Matrimonial Institutions,* II, 60 ff. For marriage and divorce in Russia, cf. Leroy Beaulieu, *Empire of the Tsars and the Russians,* II, 291 ff.

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The divorce rate for Lancaster county is abnormally high as, it will be recalled, its marriage rate was. The same cause accounts for both, *i. e.*, the number of out-of-town cases which come to the capital city. Hence, the rate itself is not significant but only the fact that it is comparatively stable, changing but little in the period covered. The rate of divorce among the Russian Germans, on the other hand, varies much more, partly because their population has not been so constant, and partly because more change is actually taking place among these foreigners than among the native people of the community.

The divorce records of Lancaster county for the past fifteen years show the following facts concerning the Russian Germans:[85]

TABLE XX. DIVORCES GRANTED TO RUSSIAN GERMANS IN LANCASTER COUNTY, WITH PARTIAL DATA RELATING THERETO, FROM 1900 TO 1914, INCLUSIVE

Case Number	Date	Plaintiff	Defendant	Number Marriage	Years Married	Place Married	Alleged Ground	Alimony Granted	Suit Contested	Children Affected	Nature of Decree
1	1901	Husband	Wife	1	3	Russia	Adultery		No	0	Divorce
2	1904	Husband	Wife	1	5	Nebraska	Marriage obtained by fraud		Yes	1	Dismissal
3	1905	Wife	Husband		15	Russia	Cruelty, non-support adultery	No	No	0	Divorce
4	1905	Husband	Wife	1	1 9/12	Lincoln	Marriage obtained by fraud, cruelty		No	0	Divorce for cruelty
5	1905	Husband	Wife	2	1 8/12	Nebraska	Cruelty		No	0	Divorce
6	1906	Husband	Wife	1	3	Lincoln	Cruelty		No	1	Dismissal
7	1907	Husband	Wife	1	1 8/12	Lincoln	Cruelty		No	0	Dismissal
8	1908	Husband	Wife	1	10	Russia	Desertion, adultery		No	1	Divorce, custody of child
9	1908	Wife	Husband	1	1 6/12	Lincoln	Cruelty	Yes	Yes	0	Divorce, maiden name
10	1909	Wife	Husband	1	1	Kansas	Marriage obtained by fraud	No	Yes	0	Annulment
11	1909	Husband	Wife	1	3	Lincoln	Desertion		No	0	Divorce

[85] For the records previous to 1909, cf. files of the *Equity Docket of the District Court of Lancaster County*. For the years 1909–1913, cf. Nebraska State Board of Health, *Divorce Records*.

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Case Number	Date	Plaintiff	Defendant	Number Marriage	Years Married	Place Married	Alleged Ground	Alimony Granted	Suit Contested	Children Affected	Nature of Decree
12	1909	Wife	Husband	1	1	Lincoln	Non-support	No	No	1	Divorce, custody of child
13	1910	Wife	Husband	1	1	Lincoln	Cruelty, non-support	No	No	1	Divorce, custody of child
14	1910	Husband	Wife	2	1½	Colorado	Cruelty		No	0	Divorce
15	1911	Husband	Wife	1	½	Council Bluffs, Ia.	Minority of plaintiff, mar. obt. by fraud		Yes	0	Annulment, maiden name
16	1911	Husband	Wife	2	1	Lincoln	Cruelty		No	0	Divorce
17	1911	Wife	Husband	1	3	Lincoln	Non-support	No	No	1	Divorce, custody of child
18	1912	Wife	Husband		6	Council Bluffs	Cruelty, non-support	Yes	Yes	0	Dismissal
19	1912	Husband	Wife	1	5	Nebraska	Cruelty		Yes	2	Dismissal
20	1912	Wife	Husband	1	24	Russia	Non-support drunkenness cruelty	Yes	No	1	Divorce, custody of child
21	1912	Wife	Husband	1	1	Lincoln	Cruelty, non-support		No	0	Divorce
22	1912	Wife	Husband	1	1	Lincoln	Cruelty	No	Yes	0	Divorce, maiden name
23	1912	Husband	Wife	1	20	Lincoln	Cruelty	Yes	Yes	3	Divorce, custody of children and alimony to def't
24	1912	Wife	Husband	1	3	Lincoln	Cruelty, non-support		No	0	Divorce
25	1912	Wife	Husband	1	26	Russia	Cruelty, non-support drunkenness		No	6	Dismissal
26	1913	Wife[84]	Husband		7	C. Bluffs	Cruelty	Yes	Yes	0	Divorce
27	1913	Wife	Husband	1	1	Lincoln	Cruelty		Yes	1	Dismissal
28	1913	Husband	Wife	2	1	Nebraska	Cruelty		Yes	0	Divorce and maiden name to defendant
29	1913	Wife	Husband	2	13	C. Bluffs	Non-support cruelty		Yes	0	Divorce, partition of property
30	1913	Wife	Husband		7		Cruelty	Yes	Yes	2	Divorce, custody of child
31	1914	Wife	Husband		4	Russia	Non-support cruelty		No	0	Divorce, maiden name
32	1914	Wife	Husband	1	1	Lincoln	Cruelty	Yes	No	1	Dismissal
33	1914	Husband	Wife	1	2	Lincoln	Abandonment and cruelty		No	0	Divorce
34	1914	Husband	Wife	1	10	Russia	Cruelty		Yes	2	Divorce to defendant

The total number of divorce suits filed by the Russian Germans is remarkably small considering the proportion of the total popu-

[84] Second suit filed; cf. case 18.

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lation which they form. In the past fifteen years, 34 suits have been filed in Lancaster county, an average of a little over 2 suits per year. The average number of divorces for the county at large in the five years, 1909–1913, has been 240 annually,[86] during which period the Russian German has averaged 4.2 divorces while comprising about one twelfth of the population. In other words, if the Russian German had secured divorces in the same proportion as the population of the county in general, he would have averaged 20 divorces per year instead of 4.2.

In spite of the comparatively low divorce rate among the Russian Germans, one of their number on being told that there had been 34 cases in 15 years, expressed the general sentiment of the community by saying: "Well, that's just 33 too many." Another man, educated in a Russian college and much influenced by the writings of Tolstoi, expressed the belief that, even with the evils connected with American divorce, conditions were vastly preferable to those in Russia where an exceedingly low rate is maintained. It is his belief that families in America, on the whole, are happier and that family morals are purer.

A number of interesting facts may be noted from the above table. One is the increased number of cases in which the wife appears as plaintiff. In the first 17 instances, the husband filed the original suit in 11 cases and the wife in 6; in the last 17, the wife filed in 12 cases and the husband in 5. This is a measure of the growing independence and individualization of the Russian German woman, and of her realization that public sentiment does not force her to suffer—indeed does not approve of her suffering —at the hands of a really cruel husband. Several of these suits have been directed by American women who have employed these foreign women, usually in the capacity of home laundresses. As a rule these cases are marriages of long standing, usually contracted in Russia, and involving several minor children. Others, however, are young Russian German girls lacking in stability, who feel that they are demonstrating their degree of Americanization by their promptness in rushing into the divorce court.

A second noticeable fact is the small number of children in-

[86] Nebraska State Board of Health, *Divorce Records.*

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volved in these divorce suits. In 21 cases there were no children by the marriage; in 8 cases there was only 1 child affected;[87] and in 5 cases there were from 2 to 6 children. In six out of a total of eight cases dismissed by the plaintiff, from one to six children were involved in each, while in the 5 suits between persons of second marriage, there had been no children. These facts point very definitely to the conclusion that children are a decidedly binding factor in the family life of the Russian German; and although no general statistics are at hand, it is very probable that the presence of children is a much greater preventive of divorce in the Russian German than in the American family.

The proportionate number of divorce suits filed and then dismissed by the Russian German is more than twice as large as for the state as a whole. In 1911 and 1912, 9.4 per cent. of all divorce suits filed in Nebraska were dismissed by the plaintiffs, while the Russian Germans in Lincoln dismissed 21.5 per cent.[88] This shows their deep-seated, instinctive aversion to divorce and their willingness to withdraw under the persuasions of relatives, friends, or minister. It is also suggestive of their readiness to use the divorce court as a weapon with which to bring a recalcitrant spouse to terms, and of their litigious tendency elsewhere mentioned.[89] There seems to be no difference in this regard between men and women for in these 8 dismissals, 4 plaintiffs have been men and 4, women.

The proportion of divorces among Russian Germans who have intermarried with other nationalities is less than is generally supposed, particularly by the Russian Germans themselves. In the last fifteen years (1900–1914) there has been one intermarriage for every 6.99 marriages among the Russian Germans; while there has been one divorce among the intermarried for every 5.66 divorces. Contrary to expectation also, the Russian German has

[87] In one of these cases there were three adult children beside the one minor child affected.

[88] While large numbers are here compared with small ones, it is probable that it is a fair comparison between the Russian German and the native population.

[89] Cf. Bauer, *Geschichte der deutschen Ansiedler an der Wolga*, 109 ff.

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been the plaintiff in five out of the six divorce suits of intermarried couples.

A fact which does not appear from the table is that in many of the marriages culminating in divorce, the ceremony was performed by a civil officer instead of an ecclesiastic. This includes all the marriages listed in the table as performed in Council Bluffs, Iowa, and some of those solemnized in Lincoln. There is always something irregular about the civil ceremony among the Russian Germans because church control of the institution is so grounded in them that resort to a civil ceremony is considered a disgrace, and usually denotes such in fact. In Russia, forced marriages are as binding as the others, but in America escape is often sought later through the divorce court.

The years of marriage for the Russian German divorcees are, as for the American, chiefly short. Almost one half the total

TABLE XXI. DURATION OF MARRIAGE BEFORE DIVORCE AMONG THE RUSSIAN GERMANS, 1900–1914

Duration of Marriage	Number of Divorces	Duration of Marriage	Number of Divorces
Less than one year	6	7 years	2
1 year	9	10 years	2
2 years	1	13 years	1
3 years	5	15 years	1
4 years	1	20 years	1
5 years	2	24 years	1
6 years	1	26 years	1

number of divorces (15) were granted to persons who had been married less than two years; while 22 couples out of 34 were married less than 5 years.

The alleged ground for divorce among the Russian Germans is usually, as with divorce in general, cruelty. In 25 out of the 34 cases, cruelty is one of the grounds given and in 14 cases it is the sole allegation; while non-support enters into 11 cases. As a matter of fact, it is impossible to tell from the alleged ground what was the real cause for action; for cruelty, in divorce petitions, covers a multitude of sins. In more cases than with Americans, however, it means physical cruelty, such as wife-beating. In 3 cases, adultery is an alleged ground; in 2 cases,

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desertion; and in 2 cases, drunkenness. In 4 cases annullment is prayed because the marriage was obtained by fraud, three of the plaintiffs being husbands and one a wife.

Several of these cases disclose peculiar customs which obtain among the Russian Germans. In one instance the husband claimed he had been cajoled into marriage by the defendant, reinforced by her minister who threatened dire spiritual consequences if he did not marry the young woman, not on account of any illegal relations sustained but just on general principles. As the matter was purely one of overpersuading an unwilling suitor and involved no criminal action, the court disregarded this petition but granted a divorce on the charge of cruelty.[90] In another case, the plaintiff was accused of being the father of the defendant's unborn child, and on threat of prosecution went to Council Bluffs and falsified his age in order to secure a license. After marriage the wife confessed to having defrauded the plaintiff, and two months later he sued for a divorce on the ground of his minority and of fraud in obtaining marriage. This case is typical of a certain small class of marriages where the parties commit perjury in order to carry out their plans, and the clerk's office has no recourse on account of the characteristic American carelessness concerning birth data. A people accustomed to the most elaborate and detailed system of records such as Russia employs, come to America, and, if the end in view demands it, falsify concerning such data with the happy consciousness that nothing will come of it.

Another divorce petition throws an interesting side light upon Russian German customs. A young man in a neighboring state sent a ticket to a young woman in Russia in order that she might come to America to marry him. When the ticket arrived the young woman was married to another, and it was decided that a

[90] The petition for divorce filed in this case is an interesting commentary on the superstition of a simple-minded young foreigner, and of the manner in which matters relating to marriage among the Russian Germans are referred to the minister for final adjudication. The prompt appeal to the divorce court is also suggestive of how quickly the hope of escape through the civil authorities overcomes the victim's fear of spiritual penalties.

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certain girl who had relatives in Lincoln and who wished to come to America should use the transportation. Instead of getting off at Lincoln she ignorantly went on to the town called for in the ticket, where she was met by the young man and his relatives who tried to persuade her to marry him. When she objected, they read what they pretended was a letter from her sister in Lincoln saying that she would not take care of her; and, since the girl had expected her relatives to repay the young man for the ticket, she was in great distress. Finally the people gave her liquor, and while she was intoxicated she was married to the young man. The next day her sister arrived from Lincoln and took her to her home, and a year later the marriage was annulled.

Remarriage among divorcees is the general rule with the Russian Germans in Lincoln. There is no disposition for them to remain single, in spite of the ostracism which is practiced against divorced persons among the people in the Lincoln settlements. Tales defaming the character of the divorced person, particularly if it be a woman, soon begin to spread; and though the individuals be entirely innocent, neighborhood gossip adds the burden of suspicion to their already troubled existence. Girls in factories and laundries have been known to refuse to work beside a divorced Russian German woman of good moral character, giving as their only reason, "She's divorced." This attitude of the community tends to hasten marriage among such as are unfortunate enough to be divorced, many of them contracting new alliances at the end of the six months' interlocutory period.[91]

The effect of a new and strange environment upon the attitude of the Russian German toward marriage and divorce is plainly marked. There is a loosening of the ties very largely as a result of the lax marriage laws in our American states. The Russian German has been accustomed to publication of the banns for three weeks preceding the ceremony; but where this formality is not required by law, the way is opened for elopement and clandestine

[91] In December, 1914, a Russian German woman was granted an interlocutory decree in the Lancaster district court and less than a week later was married in Council Bluffs, returning at once to Lincoln, where she has since made her home.

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marriages. Civil, in place of ecclesiastical, jurisdiction furnishes another opportunity for moral laxity and those who have overstepped the law avoid the censure and punishment of the church by appealing to the civil authorities for the ceremony.

Ignorance and misunderstanding are the cause for a variety of incidents in which Council Bluffs, Iowa, plays the part of a *Gretna Green* where the marriage laws of Nebraska may be evaded. Every class of irregular marriage is performed there, very often in violation of the laws of both states, and through perjury of the parties. Young people under age who elope, first cousins, those who are forced to marry, and divorcees who have received their interlocutory decrees in Lincoln but a few days previous, all journey to Council Bluffs for their wedding ceremony. While the actual number of these is not large, yet the general feeling exists among the Russian Germans that whoever cannot marry in Lincoln can evade the law by going to Council Bluffs. None of these persons have ever been prosecuted, although they are often plain violators of the law, and the practice will continue so long as the authorities wink at its infringement.

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The basis for the local statistics contained in the preceding chapters (unless otherwise noted) is a *Census of the Russian German Settlements taken March 15 to April 15, 1914.* It had been the desire of the writer ever since beginning this study in 1907 to secure such material, but there were obstacles in the way. Chief among these was the exclusiveness of the people themselves. Unacquainted with such investigations, and suspicious of their purpose, any attempt to secure this information through a house to house canvass by one outside their own number would result in their "shutting up like clams" and refusing any returns. Publicity in the matter would not help, for it would only arouse more questioning, and possibly a concerted resistance to the plan.[1] The people's sense of obedience to the law had led them to give prompt and correct answers to the federal census takers, whose work had been explained through school and pulpit; but the case of a private census was different. There was no pressure which could be brought to bear upon them by law, so appeal must be made through some definite interest by persons in whom they had complete confidence.

Although the writer had enjoyed six years of acquaintance and most cordial relationships with many of the Russian German families of the settlements, it was impossible for her to make the canvass because the people could not be made to understand how one outside their own number could have other than a selfish or

[1] This is in striking contrast to the attitude of the negro population of Lincoln a few years ago, when a study of this people was made by two graduate students of the University of Nebraska. See Marsh and Davies, *Study of the Negro in Lincoln, 1904.* All that was necessary to secure the coöperation of the negroes was an announcement from the pulpits of the various colored churches of the city that investigators would call to secure information, and, without exception, they were received cordially, and obtained answers as nearly correct as the negroes were able to give. Instead of resenting it as an intrusion, the people were pleased at the attention shown them.

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sinister motive in spending time, energy, and money in such work. Hence it was deemed best to work through the people themselves, and this was made possible through the kind assistance of Mr. Jacob J. Stroh, who, as immigration agent for many years, was personally acquainted with almost every family in the two settlements. His personal interest, especially in the historical data to be secured, led him to pay particular attention to obtaining accurate returns; and he chose as canvassers men who were not only sufficiently well and favorably known to the people to secure the information desired, but men who would use care in having the answers correct. As a result of his choice, only three families out of about 1,200 who were canvassed refused the information sought, although explanations had to be given in practically every case as to the purpose of the census.

The people were frankly told that Mrs. Williams was writing a history of the Russian Germans, and that the census taken was to be preserved as a record for their children. Guaranteed by the coöperation of the canvasser and Mr. Stroh, this was often sufficient to allay the natural curiosity excited by such a canvass; although questions such as "What is she doing it for?" or "How much money is she getting out of it?" were usually asked. With the more ignorant or more recent immigrants, suspicions were aroused, and the canvassers were asked such questions as "Does it mean more taxes?" "Are they going to take soldiers for the Mexican War?" "Is Russia hunting up soldiers?" (occasioned by the query as to how many years each man had served in the Russian army); and finally, "Is somebody trying to organize a new church?"

The census thus obtained was checked with and supplemented by the school records, the city directory, the naturalization, marriage and divorce, and health records, and by information given by several of the most widely acquainted members of the community. Especial pains were taken to be accurate because the figures handled were so small that slight errors would be much more serious than when dealing with large numbers.

The public records which have been consulted for Chapter II are the *Birth Records of the City of Lincoln,* September–De-

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cember, 1899; June, 1901–December, 1914; *Death Records of the City of Lincoln,* September, 1899–December, 1914; *Marriage Records of Lancaster County,* IV–XL, 1874–1914; *Divorce Records of Lancaster County,* 1909–1914, and *Files and Dockets of The Equity Division of the District Court of Lancaster County,* 1901–1909. The incomplete and unreliable nature of these returns has been commented upon in the text. The *Bulletins of the Nebraska State Board of Health,* Nos. 1–3, and January, 1915, have been appealed to, but in addition to the incomplete character of the returns upon which they are necessarily based, the bulletins are put up in such poor statistical form as to be practically worthless.

The birth records of the city have been supplemented by the parish registers of the eight Russian German churches now in the settlements. The years covered by each of these records are as follows:

1. Evangelische Congregationale Gemeinde,	1889–1914
2. Evangelische Reformirte Immanuels Gemeinde,	1891–1914
3. Evangelische Congregationale Zions Gemeinde,	1900–1914
4. Evangelische Congregationale Salem Gemeinde,	1901–1914
5. Evangelische Lutherische Friedens Gemeinde,	1907–1914
6. St. John's Evangelische Gemeinde,	1907–1914
7. Evangelische Lutherische Emanuels Gemeinde,	1909–1914
8. Evangelische Lutherische Christ Gemeinde,	1911–1914

These are valuable records, especially as supplemental to the birth records, for they include all the Russian German population in the city until very recently, and therefore all of the christenings. Even then they are incomplete, for they do not include those who died before christening. However, the city death records provide this data, and between the two it is possible to compile a correct and complete list of births.

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UNIVERSITY STUDIES

VOL. XVI *OCTOBER* 1916 No. 4

ARTERIAL ANOMALIES PERTAINING TO THE AORTIC ARCHES AND THE BRANCHES ARISING FROM THEM

[6 Plates, 49 Figures]

BY C. W. M. POYNTER

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* *Note.*—The section arrangement above is for the benefit of the Study as a whole and is not meant for the body of the text, where the word section refers only to the classification of the arterial variations.

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§ I. INTRODUCTION

For a number of years I have been interested in the arterial variations which have been encountered in my dissecting rooms. Notes have been made of these abnormalities and the literature describing similar conditions has been gradually collected. The more recent textbooks in anatomy devote little space to the subject of arterial variations and the classic works which have reviewed the field are no longer readily consulted; then, too, new facts have been added to our knowledge of arterial development since the most recent of the latter were published. In view of these facts it has seemed worth while to assemble the cases I have collected from the various sources and classify them according to our present knowledge of development.

I wish to take this opportunity to express my thanks to Doctor W. F. Whitney, curator of the anatomical museum at Harvard Medical School, for placing the splendid collection of the Warren Museum at my disposal for study. In the later pages I have used the results of my study freely, referring to the various anomalies as from the Warren Museum.

The following does not purport to be the entire list of all cases reported, for it was not possible with the library facilities and time I had at my disposal to consult all the works that might contain a record of such variations, but I believe a sufficient number have been collected on which to base reliable conclusions of the scope and possibly relative frequency of such abnormalities.

The bibliography at the end of this study includes not only the cases referred to in the body of the work but, in addition, many titles which I was unable to consult but which came to me on good authority. I have included the latter believing that a full bibliography on any subject has a distinct value of its own.

In this study I have confined the observations to those anomalies directly related to the aortic arches and the ventral aorta. In many cases the factor which has produced these variations

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seems to have influenced the development of the heart; since, however, no constant relationship could be discovered between the heart anomalies and those of the arches, I will reserve the study of the heart for a future paper. All cases which might be considered to be the result of known pathological processes have been excluded.

Arterial variation is but one of many irregularities encountered in the human body and in order to appreciate it fully we must consider the subject of variation as a whole, otherwise we may be inclined to think that arterial variations have a significance and perhaps an importance greater than any other anomalies encountered.

The first interest which variations had for observers, aside from being simple curiosities, was their bearing on the development of the individual and influence on the various medical and surgical procedures; then with the discovered resemblance to lower forms and the growth of embryological knowledge they assumed greater significance as one of the evidences of man's origin from the same stem as the lower animals. Duval (1884) said: "En effet de cas deux ordres de variations les unes sont un sorte de pas fait vers l'avenir, c'est á dire vers les transformations futures; les autres sont un retour vers le passe c'est á dire vers le transformations déjà subir; les premieres sont des anomalies progressives, les seconds des anomalies regressives." Bateson (1894) said: "Variation in fact is evolution. The readiest way then of solving the problems of evolution is to study the facts of variation."

That all variations should be interpreted as atavistic reminiscence is undoubtedly incorrect. A great many more variations are found in man than in the lower animals. This has been considered as an indication that the average type form is a comparatively recent acquisition, hence instability, also instability due to progressive change toward a type not yet established which will more nearly meet the requirements of the organism. Probably the best way to view the question is to consider variation as belonging to classes. Numerous observations establish a type, then by careful study we are able to classify the variations as belong-

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ing to lower types or not. If the anomaly is found in some form below man it is retrogressive, if not it is progressive. This is as far as comparative anatomy can carry us, but compartive embryology has thrown more light on the subject. Mehnert (1895) has suggested a new significance for the variations in the embryo. These variations are of themselves of great theoretic interest, they furnish us with a hint of the growth processes and are not apparently confined to the phylogenetic processes. This consideration of embryonal variations would suggest a third class of variations according to Mehnert, "Als Ungluchheiten in der Art der Entwicklung eines Organs innerhalb derselben Species oder mehrfach vertretener Organe innerhalb eines Individuums zusammenfasst."

When we find in man a condition similar to that found in some lower animal we may assume that the same factors were operative during a certain stage of development which are constant for that animal. This only suggests that at times during development man may be subject to unknown forces which are constantly operative in the lower forms. Objection to the assumption that variations dissimilar to conditions found in lower forms are progressive may be made on the ground that we are too near to judge.

Of the remote causes of variation we know nothing yet and if we assume that at a certain time unusual factors operate in a human embryo to produce a variation we are still ignorant as to what the factors are. With increased knowledge of development the number of anomalies which may be considered as indicative of atavism decrease.

Another feature of variation has been suggested by Keith (1895), who says: "An extended observation will probably show that nearly allied races are more emphatically distinguished by the kind and frequency of their anatomical variations than by what would be described as their typical structure." If this were known to be true we could only speculate as to its significance.

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§ II. VARIATION OF ARTERIES

Arterial variations early attracted the attention of anatomists and were recorded as deviations from normal; they soon interested surgeons and it is from this standpoint that Quain (1844) presented his great work; even as late as 1878 Hyrtl considered them principally for their surgical significance. Anatomists who studied the lower animals, as Cuvier (1838), recognized the similarity between some of these anomalies and the normal condition in animals and in recording the variations regularly spoke of the animals in which a similar condition obtains. The growth of the conception that a connection existed between the two, I will speak of particularly in the next section.

Baader (1866) classified a large number of the mammalian conditions as analogous to variations in man. He did not make use of the facts then known concerning development and did not speak of a similarity indicating atavism. His idea of the way in which variations occurred was new; it was in effect that the earliest vessels are arranged as a net and that the great trunks develop through the enlargement of some of these channels while others degenerate. In keeping with this theory his conception seems to have been that the number of possible variations was limitless. Aeby (1871) held the same idea and Krause (1868) made use of a hypothetical plexus in some of his explanations. The conception of an arterial net was purely theoretic with its author but it has since furnished the subject for a controversy which need not be reviewed here.

Ruge (1884) showed that variations fall into certain classes, *i. e.*, are not innumerable, and he considered that a part at least of these variations have an atavistic meaning. The work of Hochstetter, Goeppert, Evans, Lewis and others has contributed much to the general subject of arterial variation but the intimate relation of their work to the subject of this study will permit a detailed review of their researches at proper points in the subsequent pages.

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§ III. THE AORTIC ARCHES

The earliest observations on the aortic arches were made on birds; Haller (1758) recognized a stage in the chick when there were three vessels and this was antedated by the work of Malpighi who figured three arches. Pander (1817), in Tab. IX, fig. 3, showed three arches in a three-day chick; these figures are possibly copied from Malpighi, he recognized that early there were two dorsal aortae. v. Baer (1827) also saw two dorsal arteries, saying that about the fortieth hour the blood was forced around the gut in two trunks; these proceed on each side under the vertebral column, probably uniting after having been separate for a considerable distance. Serres (1830) saw between the fortieth and fiftieth hours a double aorta throughout its entire length; he affirmed that the single aorta was formed by the gradual fusion of these two trunks. He does not however seem to have had a clear conception of the branchial arteries.

Rusconi (1817) comprehended the formation of the arterial stems from the vessels of the visceral arches and described the metamorphosis from the fish type for salamander. This work was followed by that of Huschke (1817) and v. Baer (1827) for birds, and v. Baer (1828) for mammals.

Rathke is quite generally credited with originating the diagrammatic figures illustrating the fate of the aortic arches, but I believe the first figure of this kind was made by v. Baer (1828) as fig. 3, Plate IV; see fig. 1 of this study. This figure was referred to by him in his discussion of both birds and mammals and in that discussion he clearly indicates that the right arch persists in birds while in mammals the left remains. As noted in fig. 1 this is a left arch. Thomson (1830) copied the figure as a right arch and introduced a second figure of a left arch which he referred to as representing the mammalian condition.

v. Baer (1828) clearly understood the phylogenetic significance of the aortic arches, for he said, page 518: "Die erste Bildung des Arterien Systems wird aber durch die Halskeimen auf eine bei allen Wirbelthieren, bei den Fischen bleibend, bei den höheren Classen vorübergehend." Rathke (1832) made an exhaustive

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study of the branchial apparatus of different forms; he concluded, page 127: "Bei allen Wirblethieren ohne Annahme kommen in die frühesten entwickelungszeit Anlagen zu einem Zungenbein und Keimapparate vor."

v. Baer (1837), as the result of more extensive observations, revised his figure calling attention to the mistake he had made in interpretation of the carotids. The new figure was fig. 14, Plate IV, its general scheme is reproduced in fig. 2 of this study. A comparison of figs. 1 and 2 will show that his idea of the truncus arteriosus and carotids was changed, but he still believed that the subclavians arose from the third arch.

Rathke (1843) criticized the last figure of v. Baer, calling particular attention to the error in the origin of the subclavian arteries. In 1857 he issued his second work and figured the changes for the aortic arches in mammals on Plate VI, fig. 10; this I have copied as fig. 3. Aside from the point just referred to in his earlier work our principal interest in this figure is in the more detailed development of the carotids; he supposed that the basal portion of the third arch by elongation became the common carotids, and of the pulmonary arteries, he said, in speaking of the truncus arteriosus: "Es sendet nur einer von truncus (***) einen Zweig aus der sich Gableförmig theilend auf beide Lungen übergeht, und entwickelt sich darauf mit diesem Zweige und jenen erst erwähnten Canal zu der Lungenarterien, indass der andere fünft Gefässbogen vergeht."

From the time of Rathke's renowned precept of five pouches for the system of embryonal visceral arches the question of a greater number of arterial arches was not raised till van Bemmelen (1886) called attention to the presence in the embryos of reptiles and birds of a rudimentary vessel between the systemic and pulmonary arches. This caused Boas (1888) to review the evidence of his earlier work ('81–'2–'6) calling attention to the origin of the pulmonary artery in amphibia and reptilia from the sixth arch. He concluded that the pulmonary artery arose from the corresponding arches in all vertebrates and that a true arch had been overlooked between the fourth and pulmonary arches.

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He prepared diagrams illustrating the supposed fate of the arches, see fig. 4, which have since been quite generally employed.

Zimmerman (1889), acting on the suggestion of Boas, exhibited a reconstruction of a 7 mm. human embryo showing a vessel, not previously described, between the fourth and pulmonic arches; it was described as being about as large as the fourth arch and opening into that arch at both ends. Later the same year he found indications of such a vessel in an incomplete series of a sheep embryo and a complete vessel in a rabbit of the eleventh day, in the latter the vessel ran from the truncus arteriosus to the aortic root.

Tandler (1902) made a study of rat and human embryos; in the former he found irregular vascular buds and in the latter, in two embryos, a vessel running from the truncus arteriosus to the aortic arch. He said, page 341:

Da wir aber bei der Ratte so gut wie bei allen andern Säugern einen fünften Arterienbogen postuliren müssen, glaubte ich mich berechtigt diese Verbindung als ein Analogie des fünften Bogens anzusehen, und dieses um so mehr als ja der fünfte Aortenbogen bezugleich Ursprung und Verlauf bei den einzelen Species, ja bei den einzelen Embryonen, beispielweise beim Menschen, different zu sein scheint. . . . Die Annähme, dass es sich hier um eine eigenthumliche Form eines fünften Bogens handelt gewennt meiner meinung nach um so mehr an warscheinlichkeit, als ja dieser Bogen nicht nur sehr früh verschwindet, sondern sich auch sehr spät bildet.

Lehmann (1905) in a study of the pig and rabbit found in the former a vessel connecting the fourth and pulmonic arches and joined with the aortic root.

Locy (1906) reviewed the evidence in favor of a fifth arch but stated no positive conclusions although he was inclined to favor the idea of a true arch.

Soulie and Bonne (1908) studied the mole and found a vessel connecting the truncus arteriosus with the pulmonary arch; they were very insistent in the claim of a true fifth arch and called attention to the exact resemblance to the present condition in selachians. They explained the development of the vessel after the pulmonary arch on the ground of the physiological importance of the latter.

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Reagan (1912) studied the pig and found numerous anastomoses in the region between the fourth and pulmonic arches. He concluded that "A fifth vessel, very closely approximating a theoretically perfect aortic arch, can be demonstrated for the pig."

Coulter (1909) worked on the cat and found rudimentary vessels below the fourth arch and concluded that a complete fifth arch develops in the cat.

Lewis (1903) was the first to question the fifth arch. He called attention to the irregular condition of the vessels between the fourth and fifth arches and concluded: "The irregular small arteries around the fourth entodermal pouch do not, as Zimmerman believed, form a distinct aortic arch." Later (1905), he made reconstructions of the arches, together with the pouches in the rabbit, and showed not only a great irregularity of the vascular elements but that there was not sufficient evidence of a fifth entodermal pouch to warrant the claims of six arches, and that the question of the homology of the arch from which the pulmonary artery sprung was, in mammals, still an unsettled one.

In the light of recent work on the early vessels of the embryo it is not sufficient simply to find a vessel to prove the existence of a fifth arch. From my study of rabbits and the negative evidence which the collected variations furnish, I am inclined to accept Dr. Lewis's conclusions. The problem has been particularly covered recently by Bremer (1912), who says:

> While not wishing to go too deeply into the controversy on the presence or absence of a sixth aortic arch, I may say that it seems to me that the solution should come from further study of the entodermal pouches, of the branches of the nerves and the cartilages of the region. . . . As far as the early development of the vessels is concerned there is nothing certainly to prove the presence of an interpolated arch.

Quite recently new interest has been given the pulmonary arch and arteries. If the pulmonic vessel is a true arch it has undergone great modification and its interpretation is not as simple as had been supposed. Reagan (1912) says that both the pre-pulmonic caecum and the pulmonic vessel "seem to have been greatly modified, if they ever resembled closely the parts anterior which have generally been considered their homologues." Of the pul-

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monic arch, Bremer (1912) says: "In the strictest sense the arch extends only from the dorsal aorta to the pulmonary artery; the ventral part of the vessel usually called the arch is really the ventral aorta."

The development of the pulmonary arteries is readily understood by reference to Bremer's work (1902–6) which shows that Rathke's error was due to a failure to study the early development of the vessels, the condition which he figured being a later stage; see figs. 3 and 5. The arteries in the earlier stages develop one on each side and shift to the left with the growth and torsion of the truncus pulmonis about the bulbus aortae.

The subclavian arteries already referred to, fig. 3, Rathke (1857) considered arose as figured and arrived at the adult condition by a shift of the arch and a coalescence of the roots of the subclavian and carotid. This explanation was accepted till 1888 when Mackay presented a study of the subclavians in the chick. This was followed by the work of Hochstetter (1890), Goeppert (1908) and Evans (1909) for mammals, which established the origin of these arteries from a number of segmental arteries, variable in number, from the dorsal aorta. This work agrees with or explains the variations of the subclavians so frequently encountered. Figs. 5 and 8 illustrate the possibilities of origin of these arteries.

We are indebted to Hochstetter (1890) and to its further elaboration by Kemmetmüller (1911) for the correct interpretation of the origin of the vertebral arteries. Fig. 6 illustrates diagrammatically the origin of these arteries and their possible variations.

I have reviewed the embryonal history of these vessels in order to establish a basis for classification and explanation of the variations which are to follow. While we are not directly interested in the earliest stages of the bloodvessels, all of the recent work has shown that many vessels are preceded by plexus formation, though not to the extent suggested by Baader, and this fact may account in a few cases for the formation of unusual anomalies which do not seem to belong to the general classifications.

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§ IV. COMPARATIVE ANATOMY.

As already intimated, early observers were impressed with the resemblance of certain variations encountered in man to conditions which were type forms for the lower animals and this led to early group classification of these anomalies according to the arrangement of the trunks which sprung from the aortic arch. While many of the variations may be explained by the figures developed in the preceding section, there are others relating particularly to the arch which cannot be so explained. Among mammals in which the same primary arrangement of arches occurs and in which the same parts of the arches atrophy a difference in types is found. For the sake of brevity we will speak here only of the general principles and leave details of type for the later sections.

Turner (1862) believed that the modification of the early vessels brought about by the movement of the heart into the thorax was responsible for the various forms encountered. While more recent embryological observations have more fully explained the definitive arches and subclavians and have confirmed the migration of the heart, they have failed to detect differences in migration or other factors which would explain the various types extant. Dr. Owen (1868) suggested that the best service of the body economy would determine the type, but in the light of recent biological studies we must look for a more tangible factor. Many exhaustive observations have been carried out in attempts to throw light on the subject but it will not be profitable to consider them here for they simply furnish morphological data.

It seems to me that the point of particular interest to us in this study is the relation of human variation, if any, to type forms in the lower animals and the significance of variation per se. An idea which has been most popular is that the type of chest shape and the degree of descent of the heart are determining factors of the normal. Observation has failed so far to establish a relation between chest shape and the anomalous arrangement of the branches of the arch, possibly because it is of a transient character. As to the significance of an animal type in man we may

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quote Keith (1895): "It is doubtful if one can legitimately construe this . . . as an atavistic tendency; more probably it has no more morphological worth than the degree of interdigital webbing."

Parsons (1902) has made an exhaustive comparative study and as a result of this thinks Keith is not warranted in drawing the above conclusion from the data available. He very strongly favors the idea that the comparative breadth or narrowness of the upper opening of the thorax is the chief determining factor in the arrangement of the trunks springing from the aorta. In respect to variations from the normal types among lower animals, all observers are agreed that they are unusual; from this fact he concludes: "These human anomalies are quite new and tentative attempts to meet some changed condition in man as progressive variations which may or may not become more common as time goes on."

For the sake of comparative interest in taking up the various classes of anomalies the animals having a similar condition as normal will be listed.

§ V

I. IRREGULARITIES IN THE DEVELOPMENT OF THE TRUNCUS COMMUNIS ARTERIOSUS

The irregularities in this section will involve structures which belong in development to the heart, but I have chosen to consider them with the arteries because such cases are generally reported with vascular anomalies and because division from a purely developmental standpoint is impracticable. The close association of this, or, more properly, these structures, with the general development of the heart is suggested by the fact that in almost all of these cases of anomalous development there are associated cardiac defects, the most frequent of these is incomplete interventricular septum. Later it will be necessary to review briefly the development of these structures when associated heart defects will be referred to in detail.

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A. Absence or Imperfect Development of the Aortico-Pulmonary Septum

Irregularities in the development of the proximal portion of the aorta and the pulmonary arteries can only be appreciated by comparison with the various embryonal stages. As briefly reviewed on page 10 the process of development of the aortico-pulmonary septum is seen to be a complicated one and probably it is dependent on many factors. That some of these are coupled with the development of the heart there can be no doubt; this is suggested by the fact that in case of absence of the septum (persistent truncus communis) the ventricular septum is frequently rudimentary and is always defective at the base. The common trunk may open from the right side of the common ventricle as in an early stage of development or when the heart is well developed it may open from both ventricles over the defect in the interventricular septum. When the aortico-pulmonary septum is entirely absent the common trunk gives off the two pulmonary arteries separately from its lateral or dorsal wall and continues as the normal ascending aorta; see fig. 5. The common trunk is generally considered as the homologue of the aorta and the case is referred to as lacking a pulmonary artery, but this is incorrect if we are dealing with a truncus arteriosus in which the septum has failed to develop. It is the structure from which both the aorta and pulmonary arteries are differentiated and consequently represents both in an imperfect state of development. If there is no other defect in the region but the absence of a septum the pulmonary arteries will be given off one on each side of the common trunk. This condition is extremely rare, Keith (1909).

The septum may begin to develop normally, then be arrested; in such cases a truncus communis arises from the heart, then divides into an aorta and pulmonary trunk, Clarke (1885). The septum may be present but defective; in Rokitansky's case (1875) the external appearance was very much like that of the case just cited, but a remnant of septum was present in the common trunk. If the factors producing the anomaly have only a minor influence,

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they will be indicated by a communication between normally differentiated arteries, Hektoen (1905).

Not all cases of a single trunk from the heart belong to this class of irregularities. The cases of Farre (1814) and Foster (1846), Vierordt thinks, are cases of atresia of the aorta; atresia of the pulmonary artery will be discussed on page 14. Since these cases seem to represent arrest of development of the aortico-pulmonary septum and are in a measure independent of the accompanying cardiac defects I have classed them together.

The following represent all of the degrees of the anomaly included in section I, *A*:

Wilson (1798), Standert (1805), Lawrence (1814), Meckel (1816), Tiedemann (1825), Breschet (1826), Martin (1826), Mayer (1827), Blumhardt (1834), Crisp (1847), Dubrueil (1847), Clark & Owen (1848), Toynbee (1849), Hale (1850), Chevers (1851), Deutsch (1851), Hyernaux (1851), Pozzi (Chevers 1851), Vernon (1856), Bernard (1860), Wilks (1860), Turner (1862), Fraentzel (1868), Hickman (1869), Messenger (1873), Rokitansky (1875), Baginsky (1879), Crocker (1879), two cases, Caesar (1880), Peacock & Reed (1880), Rickards (1881), Grant (1883), Berrand, Barry & Rachet (1884), Brewer (1885), Brocq (1885), Clarke (1885), Barbillon (1886), Ziegenspeck (1888), Muhr (1889), Pryor (1889), d'Renzi (1889), Klipstein (1890), Charrin & Le Noir (1891), Girard (1895), Gallois (1896), Cade (1897), Cazin (1897), Petschel (1897), Civatti (1900), Orlowski (1902), Gutkind (1903), Lefas (1904), Rispal & Bay (1904), Keith (1909), Wenner (1909), Dickson & Fraser (1914).

B. Atresia of the Pulmonary Artery Usually Accompanied by Perforate Septum Ventriculare or Patent Ductus Arteriosus

Perhaps no form of cardio-vascular defect is more familiar to the general student than pulmonary stenosis, on account of its comparative frequency and marked clinical manifestations. It has been exhaustively studied by Kussmaul (1865), Rauchfuss (1878) and Vierordt (1898), consequently I will not review the large literature but will confine this classification to the cases in which the pulmonary artery is not functional.

In the cases of atresia of the pulmonary artery, as in other anomalies, different degrees of the defective development are to be found; *i. e.*, all of the variations from a normal artery with ob-

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literation of its cardiac opening to a slender fibrous cord in the normal position of the artery. It seems questionable however whether the same factors have always been operative in producing these two extremes; see fig. 35.

The case of Weiss (1875) is interesting as representing atresia in the conus, the pulmonary valves were present and the artery otherwise normal. The most frequent site of obliteration is a narrow band completely constricting the lumen of the vessel in the wall of the ventricle; it may however extend for a variable distance on the arterial trunk. When the artery is represented by a fibrous cord the aorta is usually very large and by its position, opening over both ventricles, suggests an unequal division of the truncus arteriosus by an anomalously placed aortico-pulmonary septum rather than a degenerative process or arrest of development of the pulmonary artery after it has been differentiated. The theory that the condition is due to a foetal endocarditis is generally giving place to the opinion that a developmental disturbance is the causative factor.

This anomaly is in the majority of cases coupled with defective development of the septum ventriculare. Rauchfuss only knew of fourteen cases in which the septum was complete and six of these were his own. It is interesting to speculate on the relation between the two conditions and I am inclined to think from the evidence at hand that the obliteration of the pulmonary artery is the primary condition and that the failure of the ventricular septum to close, like the persistence of the ductus arteriosus, is in the nature of adaptation. The pulmonary circulation is usually carried on through a patent ductus arteriosus but in rare instances this closes normally when the bronchial arteries enlarge and assume the added function, Meckel (1816). This is one of the most remarkable examples of structural adaptation that has been recorded.

Fig. 33 is an example of the usual appearance of the anomaly and the following cases are illustrative of its varying degrees.

Fleischmann (1815), Breschet (1826), Cerutti (1827), Mauran (1827), Lediberder (1836), Laurence (1837), Mansfeld (1843), Chevers (1846), Peacock (1848), Wallis (1850), Bednar (1852), Clar (1857), Marey

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(1857), Meyer (1857), Sturock (1859), Hervieux (1861), Rauchfuss (1864), Arnold (1868), Vulpian (1868), Semple (1870), Peacock for Royds (1870b), Peacock (1871), Peacock (1874), Heineman (1878), Crocker (1879), Schrötter & Chiari (1879), Luneau (1880), Stifel (1880), Cronk (1881), Turner (1883), Ashby (1884), Hayward (1884), Leo (1886), McKee (1887), Habershon (1888), Murray (1888), Northrup (1888), Bingham (1889), Wagner (1889), Griffith (1891), Moore (1892), Burgess (1893), Probyn-Williams (1894), Grothe (1898), Löwenthal (1900), Thomson & Drummond (1900), Champeter & Carton (1903), Schreiber (1903), Cohn (1904), McCrae (1906), Keith (1909), Hebb (1913), Milland (1914).

C. Transposition of the Aorta and Pulmonary Artery

Abnormal positions of the great vessels coming from the heart have generally been discussed under the head of "transposition of the aorta and pulmonary artery" and reported cases are generally found in connection with accounts of congenitally defective hearts. Transposition, like the conditions considered in the preceding sections, seems to bear a very close relation to cardiac development and is most frequently found in conjunction with defective septum ventriculare.

It is not necessary to develop the subject in detail, for the work of Rokitansky (1875) still stands, in spite of recent contributions to the history of development, as the most lucid and complete discussion of the subject that has been made. Although the anomaly belongs in part developmentally to the heart, it is included in this study because it is generally reported as an arterial variation. In order to classify the types of the anomaly in harmony with recent discoveries it will be necessary to review the points of development and the theories advanced concerning the etiology of the condition.

The more recent investigations have shown that the bulbus cordis of more primitive forms is represented in the mammalian heart, Greil (1903), early forming part of the anterior limb of the heart; then it is absorbed partly into what becomes later the right ventricle and partly into the truncus arteriosus. The elongated truncus arteriosus becomes differentiated into the aorta and pulmonary artery through the aortico-pulmonary septum, which

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appears at the cephalic end of the truncus and grows proximally to unite with the distal and proximal bulbar swellings and finally its interventricular border is attached to the interventricular septum, while dorsally it probably assists in forming the pars membranacea septi. During this complicated process of division of the elongated truncus the aortico-pulmonary septum describes a spiral in a clock-wise direction of about 135 degrees. In lower forms (*Lepidosiren*) this spiral is carried for 270 degrees, Robertson (1913), p. 195. Distally the septum extends laterally, dividing the truncus into a dorsal (pulmonary) and ventral (aorta) compartment, fig. 18 I. Proximally the rotation of the septum through 135 degrees has changed the relations so that the dorsal compartment is the aorta and the ventral compartment is the pulmonary artery, fig. 18 II. Through the rotation of the ventricular cardiac loop which has been going on while this process is being completed in the truncus, by the time the aorta and pulmonary artery have become independent vessels they have established definite relations with the left and right ventricles, fig. 18 III. We may consider this region as made up of four separate elements, viz., truncus arteriosus, bulbus cordis, ventricular limb and arterial limb.

The normal movements of rotation during development may be reversed, that is rotation may be counter clock-wise. When all the viscera share in this condition it is known as situs viscerum transversus. More than three hundred cases have been reported and an analysis of them shows that many are in every respect normal aside from the fact that the viscera and their arrangement is a mirror picture of the normal, Gruber (1865). What factors are operative in the production of situs viscerum transversus is not known. v. Baer described a chick which had rotated in the reverse direction and suggested that this might be the cause of the condition. Thomson (1830) accepted this theory, but it is wanting in proof. I have very carefully reconstructed the viscera of such an embryo which I have in my collection and find that in this specimen all structures are normal in position and development. Another theory which has been advanced by several authors, Virchow (1861), is that situs trans-

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versus is the result of mechanical influences acting through the persistence of the right-sided umbilical and omphalomesenteric veins. Dareste (1877) and Fol & Warynski (1881) have produced the condition experimentally, but have added little to our knowledge of its etiology. The orderly reversal of structures in true situs transversus does not always occur, Lochte (1894) having collected thirteen cases in which only part of the viscera had rotated in the wrong direction.

It has long been recognized that the heart may be transposed while the abdominal viscera and the lungs are normal. This condition is known as dextrocardia. A review of the literature shows that observers have no clear idea of this congenital condition, for cases of pathologically displaced hearts are frequently reported under this head and clinical diagnoses are frequently made notwithstanding the fact that the condition is extremely rare.

Both in cases of situs viscerum transversus and dextrocardia alone the heart and great vessels may show anomalies similar to, *i. e.*, mirror pictures of, those encountered in individuals who are normal except for the defect in question. It follows that the anlage of the heart not only does not always follow the other structures either in situs solitus or situs transversus but that one loop may be normal and one or both of the other loops transposed. Lochte (1898) formulated the general conclusion, "Jede korregierte Transposition bei situs solitus ist einfache Transposition bei situs transversus."

The cases of situs viscerum transversus are too numerous to burden this report with their repetition, but I have included the following cases of dextrocardia for the benefit of those who may be interested in their more careful study.

Eschenbach (1769), Abernethy (1793), Otto (1816) 2 cases, Breschet (1826) 2 cases, Meckel (1826), Otto (1829), Jasinski (1861), Falck (1877), Kriezer (1880), Pope (1882), Kundrat (1888), Grunmach (1890), Graanboom (1891), Lochte (1894), Paltauf (1901), Nagel (1909), Geissler (1911).

As has been shown, we cannot consider the anomalous position of the great vessels independently of the heart, and before we

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can attempt to classify them we must understand the theories that have been advanced accounting for their production. Rokitansky (1875) believed that if the concavity of the aortico-pulmonary septum be reversed the relative position of the aorta and pulmonary arteries would be reversed. Since the septum is movable all degrees of such deviation could occur. He described and figured sixteen different forms of transposition which he believed could occur, due to different degrees and combinations of deviation and nonunion of the aortico-pulmonary septum and the septum interventriculare. In the light of recent work, Robertson (1913), there are inconsistencies in his figures which in a measure destroy the classification. Also he considers a ventricle, even when furnished with a bicuspid valve, as right, so long as it occupies a position to the right of the other ventricle. This method of interpreting ventricles leads to some confusion which may be avoided if we identify the ventricles as bicuspid and tricuspid ventricles.

Keith (1909) suggested that the atrophy of the bulbus cordis around the pulmonary artery is responsible for transposition. He, however, was apparently unaware of the function and development of the spiral valve in the dipnoan heart which carries the rotation two hundred and seventy degrees and would therefore reverse the position of the aorta and pulmonary artery and accordingly vitiates his theory and spoils his diagram (Robertson 1913).

Robertson concluded from a study of the lower forms that "If the bulbus cordis develops as a short straight tube without any disparity in the length of the walls of its middle segment, no torsion of the vessels, that is the aortico-pulmonary septum, will take place, the middle part of the bulbus cordis where it should occur being so to speak wiped out." Since the position of the great vessels is determined by the position of the proximal bulbar ridges and these, theoretically, may occupy any position, the aortic and pulmonary orifices may be found with the aorta in front of the pulmonary artery and rotating clock-wise at any point in an arc of 270 degrees, or rotating counter clock-wise at any point in a similar arc the pulmonary orifice may be rotated about the aorta.

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Less than normal torsion, that is a rotation of the pulmonary to the left about the aorta through an arc of 90 degrees, may occur with no physiological disturbance, for the ventricular loop adapts itself to the slight abnormality and the structures as a whole develop along normal lines. Such a condition is easily overlooked and is only important as illustrating a stage of more extreme conditions. Robertson (1913*a*) has reported four such cases and I have observed the condition in a foetus with rachischisis.

More than normal torsion, that is the pulmonary artery occupying a position in front and to the right of the aorta, is also likely to be overlooked and will not disturb the general development. The condition is perhaps most interesting as suggesting the reptilian condition. The case of Crocker (1880) is illustrative.

All of this type of anomalies encountered cannot be explained by the torsion of the septum, and to account for these Lochte (1898) has suggested that the ventricular loop may twist normally or the reverse independently of the other parts of the heart. What factors determine the direction which the ventricular limbs will take are unknown, but it seems reasonable to suppose that they might take a reverse direction without affecting the rest of the heart.

Lewis (1915) has accepted this theory and by modeling the heart with the ventricular loop in reverse rotation has shown that such development is possible. Lochte (1898) carries the theory farther and supposes that a left-to-right twist of the left around the left deviation of the interventricular septum, may occur and bring about a transposition of the tricuspid and bicuspid valves.

To make a classification we may consider the truncus arteriosus, aortico-pulmonary septum, and ventricular loop acting independently. The truncus, leaving out intermediate positions, may assume three positions: (*a*) nonrotation (transposition); (*b*) rotation to the right (situs transversus); (*c*) rotation to the left (normal). The ventricular loop may rotate normally or the reverse, situs transversus. This will give six possible positions or combinations, of which one is the normal and another is the mirror of the normal or situs transversus. Of the four remaining combinations two may be discarded, since they are physiolog-

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ically normal, Crocker (1879); they are represented in figs. 22 and 23.

The two remaining combinations are generally known as transposition of the aorta and pulmonary artery; they may be described as follows:

1. A failure of rotation of the aortico-pulmonary septum in a heart in which the ventricular loop has rotated normally. The aorta is situated in front of the pulmonary artery and opens from a tricuspid ventricle. This is the most frequent form of transposition, fig. 20.

2. A failure of rotation of the aortico-pulmonary septum in a heart in which the ventricular loop has rotated in the reverse direction. The aorta is situated in front of the pulmonary artery and opens from a tricuspid ventricle. The condition is the mirror picture of "1" and might be found in a case of situs viscerum transversus. For explanation see fig. 21.

3. A group of cases which do not fall in either "1" or "2" have been encountered. The aorta is in front of the pulmonary artery and opens from a bicuspid ventricle. The condition is very unusual and I know of no theory to account for the anomaly which does not present great difficulties. I have offered the theory of Lochte, which Wenner (1909) thinks is satisfactory, as presenting the most logical explanation; see fig. 24.

The following illustrative cases are arranged according to the classification just given for transposition:

Transposition, Class A: Langstaff (1811), Baillie (1812), Farre (1814), Lawrence (1814), Meckel (1816), Otto (1816), Wolf (Ref. Kreysig 1817), Kreysig (1817), Nasse (1821), Müller (1822), d'Alton (1824), Burkart (1825), Tiedemann (1825), Breschet (1826), Bock (Ref. Cerutti 1827), Holst (1836), Martin (1839), Ducrest (1840), Ewen (1840), Friedberg (1844), King (1844), Beck (1846), Parker (1847), Jackson (1849), Parker (1849), Johnson (1851), Ward (1851), Keil (1854), Peacock (1855), Meyer (1857), Reynolds (1857), Hervieux (1861), Cockle (1863), Libert (1863), Meigs (1867), Arnold (1868), Fränkel (1870), Kelly (1871), Pye-Smith (1872), Ogston (1874), Barlow (1876), Maier (1876), Elliot (1877), Janeway (1877), Martin (1877), Babesiu (1879), Chiari (1879), Mackenzi (1879), Mazzotti (1879), Lees (1880), Ashby (1881), Kleinschmidt (1881), Peacock (1881), Talini (1881), Bianchi (1882), v. Etlinger (1882), Holl (1882), Peacock (1882), Pope (1882), Scott (1882), Crocker (1883),

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Gelpke (1883), Marchand (1883), Turner (1883), Combes & Christopherson (1884), v. Maschka (1884), Shattuck (1884), Toennies (1884), Tooth (1884), Bull (1885), Durozier (1885), Epstein (1886), Bury (1887), Harris (1887), Schrötter (1887), Fussell (1888), Birmingham (1889), Gampert (1889), Miura (1889), de Renzi (1889), Revilliod (1889), Audry & Lecroix (1890), Dorning (1890), Hebb (1890), Hochsinger (1891), Mirinescu (1893), Saunders (1893), Lochte (1894), Bonne (1895), Thérémén (1895), Litten (1896), Monod (1896), Rheiner (1896), Valenti & Pisenti (1896), Reifschläger (1897), Rolleston (1897), Freyberger (1898), Ramm (1899), Rolly (1899), Meinertz (1901), Peters (1901), Champeter & Carton (1903), Cowan & Ferguson (1903), Brain (1905), Chartier (1905), Ellis (1905), McCrae (1905), Apert & Brézaud (1906), Emanuel (1906), Young (1907), Keith (1909), Marchand (1909), Wenner (1909), Robertson (1911), Variot & Moranci (1911), Sato (1914).

Class B: Gamage (1818), Hickman (1869), Schrötter (1870), Graanboom (1891), Griffith (1891), Birmingham (1892), Stokes (1909), Wenner (1909).

Class C: Walshe (1842), Stoltz (1851), Gutwasser (1870), Pye-Smith (1872), Rokitansky (1875), Rauchfuss (1878), Toennies (1884), Mann (1889), Grunmach (1890), Lochte (1898), Thiele (1902), Wenner (1909).

§ VI

II. IRREGULARITIES IN THE DEVELOPMENT OF THE AORTIC AND PULMONIC ARCHES AND THE ROOTS CONNECTING THEM

I have already outlined in a preceding section the growth of our knowledge concerning the development of the aortic arches. From this we see how slowly a clear understanding of the intricate steps of development has been reached, and it is not therefore surprising that the anomalies encountered in this region were not sooner explained and classified. One of the most important steps in clearing up these cases was the paper by Wood (1859) showing the developmental process in the production of the abnormality of a right subclavian artery as the last branch of the arch, see fig. 12.

Turner (1862) collected many cases of irregularity and classified them according to the developmental error. Thomson (1863) criticized Turner for not sufficiently emphasizing by classification the difference between simple cases of right aortic arch

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and those associated with inversion of the heart. He offered a substitute classification which is in many respects less satisfactory than the one criticized. Krause (1868) added many cases to those reported by Turner and presented a somewhat different arrangement of them.

A review of all that has been offered in the literature concerning the proper arrangement of the abnormalities under consideration tends to impress one with the fact that no single classification will meet all requirements. I do not offer this arrangement as an improvement on what has gone before, but as the simplest method of presenting the material collected. A few cases in which there is marked disagreement from the explanation of the monographs cited above will be discussed, but minor differences will not be referred to, because of lack of space and not because they have been overlooked.

A. Persistence of One or Both Pulmonary Arches

Abnormalities in the development of the pulmonary arches are rare, except the condition of persistence of the ductus arteriosus. This may be accounted for by supposing that this arch develops after the factors which produce the anomalies we have been considering have ceased to be operative. Bremer (1908) has shown that the truncus pulmonis absorbs a part of the pulmonary arches, so that the left pulmonary artery springs from the truncus while the right pulmonary artery represents in its proximal portion a part of the right pulmonary arch. This point should be kept in mind in interpreting cases of absence of the aortico-pulmonary septum like that of Clarke (1885).

Persistence of both pulmonary arches is very rare; the only cases with which I am familiar are those of Breschet (1826) and Peacock (1868). In the former the aortic arch was normal, the common pulmonary artery short and from its left branch the ductus arteriosus extended in the usual way. From the right branch of the pulmonary artery a slender artery extended upward to the right, joining the subclavian artery in its proximal portion.

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In the latter case the development is not so regular; Breschet's case is illustrated in fig. 30.

Persistence of the right arch with atrophy of the left (ductus arteriosus) is not so unusual as persistence of both arches. When the development of the vascular arches is otherwise normal a right pulmonic arch (ductus arteriosus) may persist; it would seem that if the normal developmental relations are maintained it should join the proximal portion of the subclavian and represent in its distal part a segment of the right dorsal aorta. This would correspond to the position on the left or the position it occupies in cases of right arch persisting, Abernethy (1793); however in the cases of Gruber (1846), Jackson (1875) and Hildrith (1880) the vessel joins the innominate just before its division. The explanation of this condition presents some difficulties especially in the light of other anomalies of the arch.

A right arch persists occasionally in cases of right aortic arch, although this is not the rule: Abernethy (1793), Breschet (1826), Otto (1824), Ollivier (1861), Quain 1844) and Lockwood (1884). In these cases it passes from the right pulmonary to the aorta at a point below the origin of the right subclavian. In cases of situs viscerum transversus the left arch usually persists at least till birth, but in the cases of Arnold (1868) and Griffith (1891) the development of the right arch obtained as in the cases of right aortic arch above.

Persistence of the left arch to the time of birth and its later obliteration was known to Galen and its place in the foetal circulation was described by Harvey. The persistence of the arch, ductus arteriosus Botalli, is not a rare anomaly and it is frequently combined with other developmental defects, having to do particularly with the circulation of the lungs.

The cause of this anomaly has been sought indirectly in endeavoring to discover the process which produces normal occlusion. Two main factors have been suggested as responsible for the obliteration of the ductus arteriosus: (*a*) lowering of the blood pressure in the ductus after birth and (*b*) the difference in the histological structure in the ductus and the connecting blood-vessels. Recently Faber (1912) concluded that the obliteration

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is due to stretching; this stretching occurs through the force of the left pulmonary artery being filled with blood. Stienon (1912) recognized the changed relations dependent on the establishment of the pulmonary circulation but thought that the ductus also becomes compressed by the expanding left lung.

Taking into consideration then the three theories of closure, *i. e.*, decreased blood pressure, absence of muscular fibers in the wall of the ductus and mechanical influences, a study of the cases in which the ductus remains open would suggest that more frequently a condition of pressure in the vessels, similar to that existing before birth, is the most important element although no doubt the other factors, or rather the disturbance of their action, may have an influence.

As indicated above the factors producing situs transversus and right aortic arch seem to have little influence on the development of the pulmonic arch and in these conditions when the ductus persists it may join the descending aorta, Dubrueil (1847), Chartier (1905),—or it may open into the left subclavian when that vessel is the last branch of the arch. This condition should not be confused with double aortic arch, for in both there is a vascular ring about the trachea and esophagus.

The following cases illustrate the union of the ductus with the left subclavian artery when it is the last branch of the arch:

Klinkosch (1766), Cailliot (1807), Obet (1808), Bernhard (1818), Hermann (1830), Ewen (1840), Greig (1852), Fick (1854), Tüngel (1862), Broader (1866), Cameron (1871), Combes & Christopherson (1884), Lane (1887), Riche (1897), Garnier & Villemin (1909).

Persistence of the left arch, ductus arteriosus Botalli, is not a wide departure from the normal and cases with or without other developmental anomalies in conjunction are numerous. Variation in the position of the distal end presents a point of some interest. Normally during development when the arch is formed it is joined to the dorsal aorta at a point slightly above the definitive subclavian artery; later in the adjustment of parts it is frequently found below the subclavian origin. It would seem that there has been a disturbance of the normal shifting process in those cases in which the ductus joins the subclavian artery instead

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of the aorta, Reinemann (1754), Breschet (1826), Quain (1844), Pl. 7, fig. 2; see fig. 28, Bochdalek (1867).

A still more interesting variation is that in which the left subclavian artery is the continuation of the ductus and is entirely separated from the aorta, Holst (1832) and Hildebrand (1842). These cases have been incorrectly classed with that of Osler (1880) and others, see page 40, which have a very different basis for their formation.

Strassmann (1894) has very fully reviewed the subject of the patency of the ductus arteriosus, so it will not be necessary for me to review it farther, since no new details have been encountered. See figs. 27, 28, 30, 33 and 34.

The following references will illustrate the various conditions under which persistent ductus arteriosus is found and will suggest the frequency of occurrence:

Obet (1808), Langstaff (1811), Baillie (1812), Cailliot (1812), Farre (1814), Meckel (1816), Kreysig (1817), Tiedemann (1825), Breschet (1826), Bock (Cerutti 1827), Mauran (1827), Holst (1832), Chassenat (1836), Walshe (1842), Quain (1844), Beck (1846), Gruber (1846), Babington (1847), Chevers (1847), Crisp (1847), Peacock (1847), Bernutz (1849), Chevers (1851), Johnson (1851), Ward (1851), Hale (1852), Rokitansky (1852), Keil (1854), Willigk (1854), Luys (1855), Clar (1857), Langer (1857), Meyer (1857), Sturock (1859), Pannard (1860), Hervieux (1861), Ollivier (1861), Almagro (1862), Duroziez (1862), d'Bary (1864), Rokitansky (1864), Schnitzler (1864), Ramsbotham (1865), Gerhardt (1867), Glas (1867), Arnold (1868), Walkhoff (1869), Peacock (1870), Semple (1870), Cameron (1871), Pye-Smith (1872), Fagge (1873), Jackson (1875), Martin (1877), Walsham (1877), Franck (1878), Allen (1879), Peacock & Reed (1880), Hildrith (1880), Lees (1880), Luneau (1880), Malherbe (1880), O'Sullivan (1880), Ingendahl (1881), v. Etlinger (1882), Holl (1882), Scott (1882), Abercrombie (1883), Thoma (1883), Ashby (1884), Berrand, Barry & Rachet (1884), Combes & Christopherson (1884), Coupland (1884), Foulis (1884), Holt (1884), Darier (1885), Vilon & Lévèque (1885), Barbillon (1886), Lane (1886), Leo (1886), Fussell (1888), Habershon (1888), Murray (1888), Hopkins (1889), Rickards (1889), Schanz (1889), Griffith (1891), Laffitte (1892), Moore (1892), Boquel (1893), Hebb (1893), Hochhaus (1893), Saunders (1893), Ferguson (1894), Haury (1894), Probyn-Williams (1894), Stembo (1894), Frenkel (1896), Monod (1896), Siredey (1896), Cyon (1897), Josefson (1897), Gérard (1899), Alfieri (1900), Gibson (1900), Thomson & Drummond (1900), Ardissone (1902), Sidlauer (1902), Gutkind (1903),

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Scheffer (1903), Schreiber (1903), Letulle (1904), Chartier (1905), Apert & Brézard (1906), Ellis (1906), Carpenter (1909), Weiss (1909), Wenner (1909), Robertson (1911), Variot & Moranci (1911), Hayashi (1912), Keith (1912), Gasquet (1913), Hebb (1913), Matzfeldt (1913), Milland (1914).

The following cases are considered from the diagnostic standpoint during life: Burghart (1898), Zinn (1898), Dressler (1902), Pfeifer (1902), Starck (1902), Arnheim (1903), Bittorf (1903), Hochsinger (1907), Wessler & Barss (1913).

B. Persistence of Both Fourth Arches

The persistence of the fourth right embryonal arch in conjunction with the left arch produces a peculiar and rare anomaly. If there is a maintenance of the early embryonal condition, fig. 5, the right, posterior, arch will pass over the right bronchus and give origin to the right subclavian and carotid arteries; the left, anterior, arch will be in somewhat near the normal position of the aortic arch and will give origin to the left carotid and subclavian arteries. The arches will join dorsally somewhat below the attachment of the ductus arteriosus and will thus form a complete vascular ring about the trachea and œsophagus.

The following cases may be classified under this head:

Hommel (1737), Biumi (1765), Malacarne (1784), Bertin (1824), Zagorsky (1824), v. Siebold (1836), Hyrtl (1841), Blandin (1842), Rendu (1842), Jones (1846), Cruveilhier (1851), Thomson (1863), Watson (1877), Shepherd (1880), McKee (1887), Heller (1904), Hamdi (1906), Gladstone & Wakeley (1915).

The case of Malacarne is somewhat irregular, fig. 26, and difficult to explain. The internal and external carotids come from the arch and probably represent an absence of the third arches. Hommel's case, fig. 27, seems to represent the typical condition. The case reported by Zagorsky consists of an anterior arch which is evidently the normal one and which gives origin to the innominate trunk and the left common carotid. The posterior trunk passes between the œsophagus and the trachea, giving off the left subclavian before joining the descending aorta. It is difficult to understand how, if this right vessel is the right arch, it reached the position in front of the œsophagus; on the other hand

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to explain it as an aberrant vessel which through some need has reached the proportions of an aorta is to rob any vascular anomaly we do not understand of its embryonal significance and reaffirm the theory of Baader. This case is in some respects similar to that of Shepherd which is figured in the *Hand Book of Medical Sciences* as fig. 292. In the latter case however we must interpret the anomalous vessel as representing, in addition to the descending aorta, one of the segmental vessels and its root.

Thomson reported a condition which, while not a true arch, should be included in the classification as representing an intermediate condition. In a case of right aortic arch a fibrous cord occupied the position of the left descending aorta. A case referred to by Curnow (1875) is somewhat similar.

The case of Jones is very interesting as representing an arrest of development at a very early stage for not only do both arches persist but there are two dorsal aortae as well.

The description given by McKee is somewhat confusing, but it seems to me that this case should be interpreted as a case of right aortic arch, with anomalous blood supply to the lungs resulting from obstruction of the pulmonary trunk.

C. Persistence of the Right Aortic Arch with Partial or Complete Obliteration of the Left Fourth Arch

This condition is commonly spoken of as "right aortic arch" from which it might be concluded that the normal process of development is simply reversed on the two sides; however an examination of the cases shows a number of different conditions which fall into the following classes.

1. Persistence of the right arch, right dorsal aorta and left arch with obliteration of the left dorsal aorta.

2. Persistence of right aortic arch, left ventral root and left dorsal aorta with obliteration of the fourth dorsal root and arch on the left.

3. Persistence of the right aortic arch, left aortic arch and left dorsal aorta with obliteration of the left dorsal root.

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4. Normal condition of the arches in a case of situs viscerum transversus.

1. I have placed this type first because it would seem to be most nearly a simple exchange of the two sides in the normal development, fig. 9. The arch passes over the right bronchus and gives off first the innominate, which passes to the left, dividing into the left common carotid and the left subclavian, then the right common carotid and the right subclavian. It continues downward as the dorsal or descending aorta and sooner or later assumes the normal position to the left of the bodies of the vertebrae. This condition is usual in situs transversus but is occasionally varied, Hickman (1869).

I have already shown, section II, *A*, that it is unusual in cases of right arch, or situs transversus, to find the ductus or ligamentum arteriosum on the right, from which we must conclude that the developmental factors for the two arches, aortic and pulmonary, are quite independent of each other or that the factors determining the normal type for the pulmonary arch are less easily influenced than the other. An examination of the ligamentum arteriosum in these cases shows that there are two different dispositions of its distal end. In one type there is a dilation of the aorta opposite the third or fourth dorsal vertebra, to which the duct or ligament is attached. This dilation represents the vestige of the left dorsal aorta, Thomson (1863), Dubrueil (1847), Plate II, fig. 1. In the other type the ligament joins the left subclavian a short distance from its origin, Bernhard (1818), copied by Quain '44 as Plate VII, fig. 3. In the latter type the proximal portion of the subclavian represents the dorsal root of the left fourth arch.

Examples of this class of right aortic arch are not numerous, see fig. 29. I have been able to find only the following:

Cailliot (1807), Bernhard (1818), Breschet (1826), Cruveilhier (1831), Quain (1844), Gruber (1846), Drubrueil (1847), Thomson (1863) 2 cases, Turner (1883), Vincenzi (1886), Reid (1914).

2. This condition is found much more frequently than the preceding; its development is easily understood by referring to

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fig. 10. The arrangement of the branches from the arch is first the left common carotid, the right common carotid, the right subclavian and last the left subclavian artery. In that the left subclavian is the last branch of the arch and represents in its proximal portion the left dorsal aorta, it presents a close analogy to the condition of the right subclavian as the last branch, section II, *D*, 1.

This anomaly is not nearly so frequent as the low right subclavian, but when we compare it with the total number of right arches it is seen to be the usual type of development. It would seem that the tendency to develop is stronger in the left dorsal aorta than the left fourth arch and that when disturbing factors produce this irregularity they more readily affect the arch or they act with greater force on the arch, and the persistence of the right dorsal aorta may be looked upon as an arrest of the normal atrophic process to compensate for the obliterated canal. In the case of the low right subclavian, some disturbing factor causes an obliteration of the fourth right arch when there is an arrest of the normal atrophic process in the right dorsal aorta to compensate for this obliteration of the canal and insure a circulation to the extremity. If it is correct to view the two conditions in this light the anomalies are similar in that in each case some factor or factors causes the obliteration of an arch which normally develops and a compensating development of the right dorsal aorta occurs, see figs. 28 and 32.

The following cases are representative of this type of anomaly:

Klinkosch (1766), Schleitz (1768), Fiorati (1786), Sandifort (1793), Obet (1808), Meckel (1809), Meckel (1816), Otto (1824), Hermann (1830) 2 cases, Pommer (1840), Hyrtl (1841), McWhinnie (Quain '44), Quain (1844) 3 cases, Ewen (1845), Tiedemann (1846), Paetruban (1848), Greig (1852), Fick (1854), Meyer (1857), Schwegel (1859), Agliette (Peacock '60), Peacock (1860), Tüngel (1862), Turner (1862), Gruber (1863) 2 cases, Broader (1866), Bochdalek (1867), Barkow (1869), Cameron (1871), Watson (1877), Pertik (1880), Brenner (1883) 2 cases, Combes-Christopherson (1884), Lockwood (1884), Dittrich (1886), Gottschau (1887), Lane (1887), Lockwood (1890), Herringham (1891), Abbott (1892), Lunn (1896), Riche (1897), Brachet (1908), Annan (1909),

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Garnier & Villemin (1909), Macalester (1909), Weiss (1909), Dickson & Frazer (1914), Reid (1914), Warren Museum 1 case.

3. This group of cases would be representatives of double aortic arches except for the absence of the left dorsal root; the order of branches is a left innominate stem dividing into left common carotid and left vertebral, right common carotid, right subclavian and left subclavian. The condition is recognized by Piersol in his anatomy and figured as fig. 688; he suggests that it is the reverse of fig. 685 (our II, *D, 2*) but he does not label the left vertebral in the figure.

Brenner (1883) first explained this condition and showed the relation of the inferior laryngeal nerve to the left vertebral artery; he expressed the idea of a "widening" of the vertebral but now we know from Hochstetter's work (1890) that the vertebral and subclavian represent different segmental vessels. Brenner's case is figured Taf. 17, fig. 5, our fig. 11, and contains the additional variation of a right vertebral springing from the arch between the right common carotid and right subclavian.

4. Of this group we also have only one example, that of Fox (1824) which presents a normal arrangement of the vascular arches in a case of complete situs viscerum transversus. It may be viewed as a reversal of group 1 above, considering the body as a whole; on the other hand it is interesting in the suggestion that the factors which produce situs transversus may not always be operative in the development of the arches.

For other variations in cases of right aortic arch belonging to origin of vessels springing from the arch see III, *B, 2, g; C,* and II, *D, 2, g.*

D. Abnormal Obliteration or Persistence of Segments of the Arches or Dorsal Roots

A number of more or less limited irregularities of development are included in this section. They are grouped in this way not because they are morphologically similar, for they represent very divergent patterns, but because they represent circumscribed or local effects of the factors which have disturbed the normal course

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of development. As already pointed out, objections to this arrangement are appreciated and more data or a different viewpoint might suggest an entirely different classification.

1. Right fourth arch obliterated, right dorsal root persists and is represented in the right subclavian, which is the last branch from the arch.

2. Right fourth arch persists and is represented in the proximal portion of the right vertebral, right dorsal root persists and is represented in the beginning of the right subclavian.

3. Right fourth arch persists and is represented normally, the right dorsal root is present and is represented in the proximal portion of the right vertebral.

4. Obliteration of the fourth left arch and dorsal connection with the fifth arch, persistence of the left pulmonary arch.

5. Obliteration of the dorsal connection between the fourth and pulmonic arches, persistence of the left pulmonary arch.

6. Obliteration of the right third arch, persistence of the dorsal connection between the third and fourth arches.

7. Obliteration of the third left arch, persistence of the dorsal connection between the left third and fourth arches.

8. Obliteration of the third arch and dorsal roots beyond.

1. Right fourth arch is obliterated, right dorsal root persists and is represented in the right subclavian artery, which is the last branch of the arch.

(*a*) Cases in which the right subclavian passes between the œsophagus and vertebral column.

(*b*) Cases in which the right subclavian passes between the trachea and œsophagus.

(*c*) Cases in which the right subclavian has a pretracheal course.

(*d*) Cases in which this anomaly is seen in conjunction with irregularities in arrangement or number of branches springing from the arch.

(*a*) The origin of the right subclavian artery from the descending aorta is not a rare irregularity but perhaps on account of its unusual appearance it has received more attention than any other anomaly considered in this paper. The major portion of

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cases consist of a normal aortic arch giving rise to the right common carotid, the left common carotid and the left subclavian arteries, while the right subclavian springs from the descending aorta on its dorso-lateral aspect opposite the second or third dorsal vertebra, and passes behind the œsophagus to reach its normal position.

The condition was first explained developmentally by Wood (1859), who recognized it as a persistence of the right dorsal aorta, fig. 12, represented in the proximal portion of the subclavian. The frequency of the condition is variously estimated as illustrated by the following:

Name	Per cent	No. Cases Observed
Quain (1844)	.4	212
Tiedeman (1846)	.8	
Turner (1862)	.4	
Thomson (1863)	.6	800
Thomson (1891)	1.	500
Leboucq (1894)	.5	
Stieda (1894)	.8	
Götz (1896)	.8	
Adachi (1914)	.3	271

While the first cases were all grouped together in one class when they were analyzed, Holzapfel (1899), it was seen that they are not all alike, but fall into different classes, as I have indicated above. These cases have been explained from the developmental standpoint so frequently that it will not be necessary to repeat such explanations here; also reference to fig. 12 will make the point clear. It seems to me that one point should be emphasized in the developmental side of these anomalies; from a study of right aortic arch, see page 30, and comparing those anomalies with this one there is a strong suggestion that the important feature of the irregularity is not the persistence of the dorsal root but the obliteration of the right fourth arch. In looking for the etiology of the condition we should seek a factor or factors acting abnormally on the arch.

During the past year a case of this type was encountered in our dissecting rooms, the first in 150 bodies, which is in every way

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typical of the class; I will describe it here both to report the case and to illustrate the type.

Specimen is from a man 62 years old who died of Bright's disease; he did not suffer from *dysphalgia luxoria* and was not left-handed. Fig. 25 was drawn from the dissection.

The heart was normal, the aortic arch was normal in position and size, it gave off first the right common carotid, the left common carotid, the left subclavian and last the right subclavian. The latter vessel arose from the right dorsal aspect of the aorta opposite the juncture of the bodies of the third and fourth dorsal vertebræ, passed behind the œsophagus upward, describing a slight curve with the convexity to the left, to reach its usual position in relation to the scalenus anticus muscle. The right vertebral artery, which was the first branch given off, had the usual relations and entered the sixth costo-transverse foramen. The ligamentum arteriosum was normal and was attached to the aorta about 3 cm. above the origin of the right subclavian.

The recurrent laryngeal nerve on the right was given off in the neck and passed almost directly across to the trachea without making any downward loop. The thoracic duct divided into two trunks, of which the right was slightly the larger, opposite the fifth dorsal vertebra and emptied into the venous angle on both the right and left sides. There were no other anomalies observed in the entire body.

There are seven similar cases in the Warren Museum, which I examined and which, I believe, have not been reported. In two of these there is a definite dilation at the point where the subclavian leaves the aorta; the other cases are in no wise remarkable and all are without history.

Cases of this type are most numerous, see figs. 39 and 41, and present a simple developmental disturbance which is entirely compensated for and consequently works no ill to the individual. I have been able to collect the following cases, referring freely to Holzapfel's (1899) splendid work:

Hommel (1737), Cassebohm (Böhmer 1741), Hoffmann (1751), Mieg (1753), Löseke (1754), Ludwig (1764), Schleitz (Ref. Murray 1768), Erdmann (1772), Sandifort (1772), Pohl (1773), Walter (1785), Cruickshank (1789), Hulme (1789), Valentin (1791), Sandifort (1793), Isenflamm (1800), Meckel (1805) 4 cases, Autenrieth & Pfleiderer (1806) 2 cases, Koberwein (1810), Zagorsky (1810), Isenflamm & Fleischmann (1815), Meckel (1816) 3 cases, Otto (1816), Kirby (1818), Colles (1820) 4 cases, Meckel (1820) 2 cases, Tiedemann (1822), Stedman (1823), Godman (1824), Hesselbach (1824), Hart (1826), Cerutti (1827), Mayer (1827), Wagner (1828) 2 cases, Weber (1829) 2 cases, Green (1830) 3 cases, Hopkinson (1830), Lauth (1830), Otto (1830) 6 cases, Cruveilhier &

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Lenoir (1832), Fleischmann (1835) 2 cases, Dubrueil (1837) 2 cases, Harrison (1839) 2 cases, Liston (1839), Todd (1839), Demeaux (1841), Gorgone (1841) Ref. Banchi '07, Brent (1844), Patruban (1844), Quain (1844) 8 cases, Reid (1846) 2 cases, Arnold (1847), Demarquay (1848) 3 cases, Stachelroth (1850) 2 cases, Frandsen (1854), Cavasse (1856), Hyrtl (1859), Oehl (1859) 2 cases, Wood (1859), Peacock (1860) 5 cases, Dubrueil (1862), Turner (1862) 4 cases, Barkow (1866), Barwell (1867), Wood (1867), Barkow (1869) 10 cases, Bankart, Pye-Smith, Phillips (1869) 2 cases, Peacock (1870), Bradley (1871), Eppinger (1871), Leidy (Ref. Mears '71), Mears (1871), Pancoast (Ref. Mears '71), Pye-Smith, Howse, Davies-Colley (1871) 2 cases, Düben (1876), Krause (1876), Shepherd (1877), Zenker (1878) 5 cases, Flesch (1879), Carrier (1880), Walsham (1880), Wiltshire (1881), Brown (1882), Giacomini (1882) 6 cases, Brenner (1883) 3 cases, Ozenne (1883), Horrocks, White, Lane (1884), Collins (1885), McArdle (1885), Beisso & Giuria (1886) 3 cases, Struthers (1888), Deaver (1889), Mann (1889), Calori (1890) 5 cases, Dunn, Washburn, Targett (1890), Ledouble (1890) 3 cases, Rau (1890), Thomson (1890), Bothezat & Chatinière (1891), Thomson (1891) 3 cases, Solger (1893), Leboucq (1894) 4 cases, Faure (1895), Jacques (1895) 2 cases, Götz (1896) 2 cases, Testut (1896) 2 cases, Herrick (1897), Miura (1897), Anile (1898), Holzapfel (1899) 4 cases, Rolly (1899) (Ref. Banchi '07), Hamann (1900), Ledouble (1901) 3 cases, Blair (1902) 2 cases, Cabibbe (1901) (Ref. Banchi '07), Bouchet (1903), Duckworth (1906), Gérard (1906), Gianelli (1894) (Ref. Banchi '07), Zoia (1872) (Ref. Banchi '07), Banchi (1907), 2 cases, Pearce-Gould (1909), Geddes (1910), Hasebe (1912), Adachi (1914), Cobey (1914), Gladstone & Wakeley (1915), 7 cases in the Warren Museum.

This irregularity is very unusual in animals but the following cases have been encountered.

Meckel (Ref. Cuvier 1810) in the hedgehog, Ogilvie & Cathcart (1874) in a lamb and Smith (1891) in a rabbit.

(*b* and *c*) The condition in which the anomalous subclavian is between the œsophagus and trachea and that in which it is in front of the trachea may be considered together from a developmental standpoint, but the cases of each type will be listed separately. Fig. 5 may be used to illustrate the conditions but not to suggest the actual developmental process. There are many difficulties in the way of using the explanation which accounts for the formation of the preceding group (fig. 12) in expounding the formation of these irregularities; neither Turner (1862) nor Krause (1876) seem to have fully appreciated the fact.

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Several hypotheses have been offered in explanation of the ventral position of the proximal portion of the subclavian but none of them, it seems to me, are entirely without objection. The first assumes that the dorsal aortae unite ventral to the œsophagus. Such a process is difficult to understand in view of the way in which the common aorta normally develops; then too if a process so fundamental, apparently, as aortic development may present such an extreme irregularity we have no evidences of its having been found except in this one anomaly and always at this point.

The second hypothesis, that of Rau (1890), offered as an explanation of the general class, conceives that the anomalous subclavian has arisen by early anastomoses with the right bronchial artery. This would account for the ventral position of the vessel, but we would have to assume a very high origin for the bronchial and also that it developed much earlier than it seems to do normally. The right bronchial artery would then be a branch of the anomalous subclavian and no such condition has been reported (Holzapfel).

The third hypothesis, which is favored by Holzapfel (1899), is that an anomalous anastomosis develops ventrally between the paired descending aortae. This anastomosis occurs early, then when the lungs are laid down their relation to this aberrant vessel will determine which type, *i. e., b* or *c,* will develop. The explanation cannot be disproved but may be objected to on the ground that it denies an orderly development of the earliest vascular anlage and reaffirms the theory of Baader for this particular anomaly, in the light of all the more recent investigations which suggest that a more exact explanation may be possible.

The fourth hypothesis was offered by Banchi (1907) who thinks these cases represent a persistence of both fifth (not pulmonary) arches with atrophy of the dorsal root of the right fourth arch and the right descending aorta. We may offer as an objection to this that there is possibly still some controversy on the "fifth" arch, see page 8, but more important, that such an explanation necessitates an anomalous union between these arches ventrally, which is as great a difficulty as the general question; or if we accept his explanation of this point we still have to account

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for an atrophy of the junction of the "fused" fifth arches and the ventral aortae, see fig. 7.

The following cases represent the two conditions: *b,* cases in which the anomalous subclavian passes between the œsophagus and the trachea; *c,* cases in which the subclavian passes ventral to the trachea:

Group b (artery passes between trachea and œsophagus): Bayford (1789), Brewer (1791), Monro (1797), Herold (1812), Hesselbach (1824), Harrison (1839), Hyrtl (1841), Pigné (1847), Stachelroth (1850), Gross (1852), Peacock (1860), Brown & Brown (1868), Bankart, Pye-Smith, Phillips (1869), Bradley (1871), Calori (1890), Thomson (1891), Gladstone & Wakeley (1915).

Group c (artery is pretracheal): Hunauld (1735), Meckel (1751) in a letter to Haller (1743–56), Walter (1785) 2 cases, Cruveilhier (1831), Vittorini (1831) (Ref. Banchi '07), Dubrueil (1847), Blandin (1842), Burns (Ref. Banchi '07).

Another question in connection with these cases, which is of great interest, is the relation of the right vagus nerve to the anomalous subclavian artery. Unfortunately many reports are silent on this point but it is shown from the reports recording this relation that in some cases the nerve runs ventral to the artery and in others it has a dorsal course. Banchi (1907) suggests that the process by which the nerve reaches a dorsal position in these cases is through a secondary subclavian, which Rabl (1906) has shown is the manner in which a similar relationship is effected normally in birds.

(*d*) In certain cases of anomalous subclavian artery there are additional variations either in the number of branches springing from the arch or in their position on the arch. It is my impression from a study of these cases in conjunction with other variations that they represent two independent processes; they are included here as a separate group simply to facilitate more detailed study. The cases are all listed in the preceding groups of this class and are again listed in the proper classes under section III, so in the following list references for full detail are to the various classes of section III.

Hunauld (1735), Meckel & Haller (1751), Erdmann (1772), Sandifort (1772), Walter (1785), Koberwein (1810), Meckel (1820), Tiedemann

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(1822), Godman (1824), Wagner (1828), Green (1830) 2 cases, Lauth (1830), Dubrueil (1837) 2 cases, Demeaux (1841), Brent (1844), Quain (1844) 5 cases, Tiedemann (1846) 4 cases, Pignè (1847), Cavasse (1856), Barkow (1866), Wood (1867), Barkow (1869) 3 cases, Bankart, Pye-Smith, Phillips (1869) 2 cases, Pye-Smith, Howse, Davies Colley (1871), Carrier (1880), Giacomini (1882) 2 cases, McArdle (1885), Brodie (1888), Shepherd (1890), Thomson (1891), Abbott (1892), Lebouco (1894), Jacques (1895), Götz (1896), Herrick (1897), Holzapfel (1899) 4 cases, Banchi (1907), Warren Museum 5 cases.

For the detailed classification of the cases in this list see the following sections: III, *B*, 2, *c*; III, *C*, 4; III, *C*, 6; III, *D*, 1, *d*; III, *D*, 1, *g*; III, *D*, 1, *h*; III, *D*, 1, *k*; III, *D*, 2, *b*; III, *D*, 2, *d*; III, *D*, 2, *e*.

2. The right aortic arch is present and is represented in the proximal portion of the right vertebral artery, which seems to spring from the right common carotid. In this group conditions are the same as in group 1, except that the right vertebral springs from the right common carotid instead of from the right subclavian artery. Reference to fig. 13 will explain the method of development of the irregularity. The theory of its occurrence was first suggested by Brenner (1883) and was based on the relation of the right recurrent laryngeal nerve. This has the same relation to the vertebral artery in these cases as it bears normally to the subclavian artery of this side. It will be seen that this theory necessitates considering that the vertebral has an origin in a higher segmental artery than the subclavian, but, as is pointed out in considering the development of the vertebral, page 10, this is not unreasonable. It would seem that the disturbing developmental factors have affected just the connection between the sixth and seventh segmental arteries and the right dorsal aortic root; or perhaps the primary defect was in the connection between the segmental arteries, and the resulting anomalies, *i. e.*, persistence of the sixth segmental artery and the right dorsal aorta, are in the nature of compensation for this irregularity of development, see fig. 39.

The following cases belong to this group:

Murray (1768), Green (1839), Simon (1846), Tiedemann (1846), Dubrueil (1847), Hyrtl (1859), Wood (1859), Brodie (1888), Shepherd (1890), Abbott (1892), Solger (1893), Suzuki (1894), Holzapfel (1899), Kemmetmüller (1911) 3 cases, Hasebe (1912).

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3. This group presents a persistence of the right dorsal aorta represented in the proximal portion of the right vertebral artery; for diagram see fig. 14. The branches of the arch are normal, but the right vertebral, instead of springing from the subclavian in the usual manner, arises from the descending aorta just below the arch, passing outward and upward behind the subclavian to reach its normal position. In these cases the vertebral originates through a lower segment than the subclavian and in this respect is the reversal of group 2. If there were no other change than the persistence of the two segmental arteries and the right dorsal aorta the picture would be one of a double arch. The fact that the right arch includes a connection between the two segmental arteries instead of the right fourth root could not be appreciated from an examination of the case.

It seems to me that to explain these cases we must assume that the axillary plexus, page 10, which Göppert has shown is always present, early makes a connection with one of the upper segmental arteries, say the sixth, very near its origin from the aorta. With this pathway established the more distal portion of the segmental (sixth) atrophies; then, when the connections are established between the segmental arteries to make up the vertebral, either a more cephalic segmental will furnish the origin of the vertebral or a more distal one (seventh); in the former condition the vertebral may arise from the subclavian near the common carotid and enter a higher transverse foramen, Waldeyer (1909), or from the common carotid as in one of Brenner's (1883) cases where it entered the fourth transverse foramen; in the latter, representing this group, the persistence of the right dorsal aorta is in compensation for the absence of other vertebral connections. The vertebral enters the seventh or sixth foramen.

The following cases representing the condition have been reported:

Hyrtl (1859) 2 cases, Struthers (1875), Paterson (1884), Azuta (1905), Szawlowski (1906).

4. Obliteration of the fourth left arch and dorsal root, persistence of the left pulmonary arch. In these cases the innomi-

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nate and left common carotid spring from the ventral aorta and represent the circulation from the left side of the heart. The ductus arteriosus is patent and joins, or is continuous with, the descending aorta; at the angle formed by the two the left subclavian artery is given off, see fig. 15. It seems most logical to account for these cases as due to disturbance with the development of the left arch; in this respect they are closely allied to cases of the more numerous type of right aortic arch, II, *C*, 2; however it seems to me that probably the disturbing factor acted at a later period than it did on the right arches, *i. e.*, after the normal atrophy of the right dorsal aorta had been effected. As already indicated these cases present a different problem of developmental disturbance than the case of Holst, page 26.

Greig (1852), Struthers (1875), Osler (1880).

5. Obliteration of the dorsal root of the left fourth arch, persistence of the left pulmonary arch. This condition is evidently closely related to the preceding group. The innominate, left common carotid and left subclavian are normal, the left arch terminates with the left subclavian and the descending aorta is continuous with the left pulmonary through the ductus arteriosus. This condition seems to bear the same relation to II, *C*, 3 that the preceding one does to II, *C*, 2. The disturbing developmental factor acts on a limited area, the left fourth dorsal root, but this same local effect is seen in II, *C*, 3, II, *D*, 2 and II, *D*, 3, see fig. 16.

I know of only one example of this anomaly, the case of Steidele (1778). Valenti & Pisenti (1896) have reported a case which is suggestive of the condition although the obliteration is not quite complete; probably also some of the cases of coarctation of the aorta, which is not considered in this paper, are examples of the less pronounced effect of the same developmental disturbance.

6. Obliteration of the right third arch, persistence of the third right dorsal root.

7. Obliteration of the left third arch, persistence of the third left dorsal root.

Groups 6 and 7 may be considered together, since they are

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identical except for the side affected. In each the common carotid is absent and the internal and external carotids spring from the arch. We may consider that the developmental disturbance leading to an atrophy or failure in development of the third arch is the primary condition and that the persistence of the dorsal root is an attempt at compensation for this anomaly, see fig. 17.

The following cases are illustrative of the two groups:

Group II, *D*, 6. Malacarne (1784) double arch, same condition on each arch, Power (Ref. Quain '44), Kosenski (1867), Macalester (1886), case I.

Group II, *D*, 7. Malacarne (1784), double arch; Gottschau (1885); Macalester (1886), case II; v. Augenmayer (1906), Siegfried (1906).

8. Obliteration of the third arch and the roots beyond. This condition is characterized by the absence of the internal carotid; the condition may occur on either the right or left side and to make the classification uniform with the preceding should be divided into two groups, one for each side.

Absence of the external carotid is less frequent but does occur, Langenbeck (1841).

All of the following cases are failure of development on the left side except that of Todd, which is on the right and Fisher, which is on both sides.

Todd (1787), Koberwein (1810), Quain (1844), Peugnet (1876), Wyeth (1878), Flemming (1895), Fisher (1914).

§ VII

III. IRREGULARITIES IN DEVELOPMENT OF BRANCHES OF THE AORTA

This section will include, in addition to the variations in number and arrangement of branches springing from the aortic arch, anomalous arteries of the ascending aorta. Some of these conditions are understood embryologically, but many of them are still without satisfactory explanation from a developmental standpoint; consequently, instead of classifying them from a developmental standpoint, as has been done in the preceding sections, a simple morphological classification will be followed. The arrangement of branches in many of these groups is similar to type forms in other mammalia. It is interesting to note that through

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all classes of mammals there is variation in the arrangement of branches from the arch in the individual species. No single species or genus shows a wide variation till primates are reached, and man seems to present as anomalous development all of the conditions encountered in other mammalia. I have already reviewed, see page 11, the significance of the comparative anatomy, so it will only be necessary here to repeat that in citing under the various groups the animals presenting the same condition normally it is done simply as a point of morphologic interest and not with the idea of suggesting an atavistic relationship.

Some of the variations already included in the preceding sections will be repeated here; this applies particularly to II, *D*, 1. This seems necessary because the basis of classification for this section is different than for the preceding and it is desirable to present together all of the examples of a given type of variation.

A. Irregularities in the Branches from the Ascending Aorta

1. *Irregularities of the Coronary Arteries.*—The coronary arteries exhibit several irregularities; of these the most frequent is the presence of one or more accessory arteries. Symmers (1907) reported these present in 40 percent of cases and that they were more frequently present on the right side. This is greatly in excess of the percentage present in the series reported by Halbertsma (1863) and Banchi (1904); the latter finds that when a third branch is present it is generally a branch of the right coronary, which has a separate origin from the aorta. In a hundred observations I have found in two instances that the area usually supplied by the right coronary was furnished by two short trunks direct from the aorta; this confirms Banchi's observation.

One artery may be absent and in that case the other artery supplies the entire heart.

The arteries, one or both, may arise higher than normal from the aorta, as in the cases reported by Farre (1814), Mayer (1827), Hyrtl (1841) and Chevers (1851).

Arteries multiple: Morgagni (1761), Meckel (1817), Halbertsma (1863), Krause (1865), Brooks (1885) from pulmonary, Hepburn (1886), Banchi (1904–7), Symmers (1907).

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One artery: Fantoni (1699), Thebesius (1716), Mayer (1827), Otto (1830), Hyrtl (1841), Hyrtl (1855), Heitz (1901).

2. *Other Arteries from the Ascending Aorta.*—Bremer (1912) has shown that the ventral aorta is developed from a plexus and it seems probable that it is through the persistence of some of these early channels in connection with the aorta that such anomalies as the following are to be explained. That they are so very rare may be accounted for on the ground that this plexus is a very early formation, and is in a center of great growth activity and shifting of parts; any minor channels which might persist after the ventral aortae were established would almost certainly atrophy through pressure and lack of definite area to supply.

Thymic vessels springing from the ascending aorta have been reported by Haller (1747), Breschet (1826) and Hyrtl (1841).

Twice the internal mammary dextra has been observed arising from the ascending aorta. Such an anomaly is more difficult to reconcile with the above explanation unless we assume that the aberrant vessel of the plexus communicates with a segmental below the definitive subclavian, which in turn gives rise to the internal mammary; such a conclusion is not warranted by any developmental history of the internal mammary or any of its anomalies with which I am acquainted. The cases are reported by Böhmer (1741) and Meckel (1816).

B. Number of Branches from the Aortic Arch Less than Normal

1. One branch from the arch.
2. Two branches from the arch.

1. In these cases one branch springs from the arch of the aorta; see fig. 37. This condition is common in some of the lower mammals; the single branch divides into brachial and cephalic trunks which are arranged normally. The cases of this irregularity are not all exactly similar; in some the arch is apparently lacking and the descending aorta seems to curve over the bronchus from a junction with the ascending stem from its proximal portion; in other cases a stem springs from the top of the arch and almost immediately divides into the regular branches, suggesting that

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they have simply migrated to a common point of origin. I know of no exact explanation for this irregularity; it is not difficult to account for the fusion of the left carotid with the innominate trunk, but if the arch is normal the anomalous position of the left subclavian is more difficult to explain.

The following cases of this irregularity have been reported:

Troussières (1667), Garnier, Spon & Troussières (1729), Haller (1768) (Ref. Meckel 1816), Klinz (1787), Meckel (1816), Boudant (1829), Hyrtl (1841–59), Dubrueil (1847), Vernon (1856).

This type of development is found in the following mammals: Antilopidae, atherura, bos, capra, cervus, dasyprocta, equus, gazella, genetta, rangifer, rhinoceros, tapirus.

2. Only two branches from the arch. This condition is represented by a number of different types of arrangement which have been classified as follows:

(*a*) Fusion of the ventral aortic roots or migration of the left carotid furnishes an innominate stem with the left carotid springing from it and the left subclavian arising from the arch, figs. 31 and 36. The positions of the right subclavian and carotids on the innominate present a number of variations; the left carotid may arise from the base of the innominate or a trunk may continue for some distance after the right subclavian is given off, then divide into the right and left carotids; for these various arrangements see Keith (1895) and Parsons (1902). These cases are numerous; Quain says twenty-five times in 219 cases, which probably explains why the older anatomists considered the condition normal. Vesalius figured the condition on pages 483 and 564.

The following list is given of references encountered during this study; it is evidently in no way representative of the number of times this condition has been observed; Thomson's report (1893) and Adachi's figures (1914) show a frequency of over 10 percent. I have observed the condition only twice in my dissecting rooms; in both of these cases and also in the two from the Warren Museum, reported below, the left carotid arose from the innominate trunk quite near its base; see fig. 36.

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Vesalius (1543), Casserius (1609), Spegelius (1627), Vestingus (1641), Troussières (1668), Eustachius (1714), Heister (1717), Hunter (1717), Petsche (1736), Neubauer & Erdmann (1772) 2 cases, Meckel (1774), Huber (1777), Malacarne (1784), Neubauer (1786), Walter (1785), Burns (1809), Ryan (1812), Tiedemann (1822), Baron (Lauth 1825), Weber (1829), Lauth (1830), Hyrtl (1841), Quain (1844), Isaacs (1855), Kelly (1871), Peacock (1871), Pye-Smith, Howse, Davies, Colley (1871), Embleton (1872), Davies, Colley, Taylor (1873), Broca (1880), Shepherd (1880), Horrocks, White, Lane (1884), Deaver (1889), Freyberger (1898), Cowan & Ferguson (1903), Adachi (1914), Warren Museum 2 cases.

This condition is quite common in mammals; it seems to have been encountered occasionally in all of the primates and is probably the normal condition for Hylobates. It is the most frequent arrangement in the carnivores and has been noted in the following ungulates: giraffa, hippopotamidae, hyracidae, llama, suidae, tapirus. Among the rodents this type of arrangement is normal for lepus and has been reported for cavididae, hystricidae, lagostomus, myopotamus, octodon, sciuridae.

(*b*) This group may be termed bi-innominate; there are two trunks arising from the aortic arch and each divides into a subclavian and a carotid artery. The obvious anomaly is that the origin of the left subclavian has moved proximally on the arch till it is fused with the left carotid or that there has been a disturbance in the development of that portion of the arch between the carotid and subclavian. I have not been able to find any report of work on the developmental side of this problem.

The following examples have been reported; for illustration see fig. 35.

Biumi (1765), Malacarne (1784), Jackson (1816), Tiedemann (1822), Boudant (1829), Patruban (1844), Dubrueil (1847), Cruveilhier (1851), Broca (1880).

The bi-innominate trunks are normal for Chiroptera (Grosser 1901) and are frequently found in the following other animals: cetacea, chrysochloridinae, erinaceidae, tulpa.

(*c*) A condition of two branches from the arch, the first made up of the two carotids and the other of the two subclavians. There may be some doubt about these cases; only two have been reported, the first, Schön (1823), was referred to by Meckel in his anatomy (1817), page 111, as a case of bi-carotid bi-subclavian trunks, but Krause doubts the validity of the case; the

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second, Patruban (1844), is accepted by Krause, but Holzapfel considers this a case of low origin of the right subclavian and a bi-carotid trunk; this seems to me the correct interpretation of the case.

(*d*) This group is similar to (*a*) except for a slight modification; the first trunk divides into the right subclavian, right and left common carotids and the right internal mammary; the second trunk from the arch is the left subclavian. I know of only one example, that reported by Hyrtl (1841).

(*e*) This group is like the one immediately preceding except that a thyroid ima takes the place of the internal mammary. Cases have been reported by Isaacs (1855), Paterson (1884) and Freyberger (1898).

(*f*) In these cases there are two branches from the arch, one an innominate trunk made up of the right and left common carotids and the left subclavian, the other trunk the right subclavian. Only three examples are available; viz., Zagorsky (1809), Breschet (1826) and Dubrueil (1847). These cases are quite difficult to interpret. Krause classified Zagorsky's case as one of right arch, although there was no mention made in the original of the direction of the arch; Tiedemann figured it, Plate IV, fig. 8; there was no figure in the original, and Quain copied his figure on Plate VI, fig. 8. It seems to me that instead of interpreting these as cases of right arch we might consider them as the counterpart of the next group.

(*g*) In this group the right aortic arch takes the place of the left; from the arch proper one trunk is given off, which divides into the left common carotid, right common carotid and right subclavian, from low on the arch, *i. e.*, the descending aorta, the left subclavian arises. This condition has been reported by Henle (1843), Tiedemann (1846) and Dubrueil (1847).

C. Number of Branches from the Aortic Arch Normal in Number but Abnormal in Arrangement

1. Order of branches, innominate trunk made up of right subclavian, right common carotid, left common carotid, then left

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vertebral and last left subclavian, illustrated by fig. 43. In this group the innominate stem presents the same anomalous development that has been discussed in section III, *B*, 2 (*a*), the only difference from that section is the presence of a vertebral arising from the arch instead of in its usual position. This latter variation is brought about by the persistence of one of the higher segmental arteries and the failure to establish the normal connection with the segmental, which is represented in the subclavian; see fig. 6.

The following cases are illustrative:

Sandifort (1781), Walter (1785), Meckel (1816), Tiedemann (1822), Paterson (1884), White, Lane, Price (1883), Warren Museum.

2. This group is the same as the preceding except that the order of the subclavian and vertebral is changed; order of branches, innominate, left subclavian, left vertebral. Walter (1796 and 1805) reported a case, also Tiedemann (1822). Owen (1868) says the condition is normal for the giraffe.

3. Order of branches, right subclavian, common trunk for the carotids, left subclavian; illustrated by fig. 40. Cases are reported by Portal (1803), Tiedemann (1822), Dubrueil (1847), Trèlat (1856). This condition is found occasionally in elephants and some marsupials.

4. Order of branches, bi-carotid trunk, left subclavian and last right subclavian; illustrated by fig. 38. This arrangement of the carotids is a frequent one in the cases in which the right subclavian is the last branch of the arch.

The following list is taken from cases already reported in section II, *D*, 1, but repeated here because in the former classification the arrangement of the carotids was not indicated.

Hunauld (1735), Hommel (1737), Meckel (1751), Erdmann (1772), Sandifort (1772), Walter (1785), Green (1830), Lauth (1830), Demeaux (1841), Quain (1844), Patruban (1844), Dubrueil (1847) 2 cases, Pignè (1847), Stachelroth (1850), Cavasse (1856), Barkow (1866), Wood (1867), Brown & Brown (1868), Bankart, Pye-Smith, Phillips (1869), Barkow (1869) 2 cases, Bradley (1871), Carrier (1880), Giacomini (1882), Calori (1890), Herrick (1897), Thomson (1891), Leboucq (1894), Jacques

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(1895), Götz (1896), Holzapfel (1899), Banchi (1907), Gladstone & Wakeley (1915), Warren Museum 5 cases.

5. The order of branches is: Bi-carotid stem, right subclavian, left subclavian. Cases reported by Lauth (1830) and Quain (1844).

6. The order of branches is: Right carotid, stem composed of the left carotid and the left subclavian, right subclavian; see fig. 41. One case has been observed by Tiedemann (1822); this belongs in the general class of low origin of the right subclavian, section II, *D*, 1.

7. The order of branches is: Innominate, left subclavian, left carotid. Example reported by Weber (1829).

8. The order of branches is: Innominate, left external carotid, left subclavian. This group has been previously reported as section II, *D*, 8.

9. The order of branches is: Innominate, dividing into right subclavian, internal and external carotids, left common carotid, left subclavian. Previously reported, see section II, *D*, 6.

10. In right aortic arch the order of branches is: Innominate (left), right carotid, right subclavian. Previously reported as Section II, *C*, 1.

11. In right aortic arch the order of branches is: Innominate made up of the right and left common carotids, right subclavian, left subclavian. This is the counterpart of group 4 above; cases, which are included in section II, *C*, 2, have been reported by Annan (1909) and Macalester (1909).

12. The order of branches is: Right subclavian, right carotid, left carotid from the arch; the left subclavian from the ductus arteriosus. Reported by Holst (1832) and Hildebrand (1842).

13. Ascending aorta divides into the right subclavian, right and left common carotids; the left subclavian and descending aorta from the ductus arteriosus. Reported as section II, *D*, 4.

D. Number of Branches from the Aortic Arch Greater than Normal

1. *Number of Branches Four.*—(*a*) The order of branches is: Right subclavian, right common carotid, left common carotid, left

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subclavian (absence of innominate). The following cases have been reported:

Bergerus (1698), Heister (1717), Nicolai (1725), Winslow (1732), Palfyn (1734), Ballay (1758), Meckel (1809 and 16), Ryan (Monro 1813), Fleischmann (1815), Tiedemann (1822), Lauth (1825), Pitcard (1840), Isaacs (1855), Krause (1865).

(*b*) The order of branches is: Right common carotid, right subclavian, left common carotid, left subclavian; see fig. 44. Cases are reported by Huber (1777) and Walter (1785) and these are both figured by Tiedemann and Quain but there is no indication of the direction of the arch; Thomson (1863) thought them cases of right arch, Krause considered them incomprehensible from a developmental standpoint.

(*c*) The order of branches is: Right common carotid, left common carotid, right subclavian, left subclavian. Cases reported by Walter (1805) 2 cases, Krause (1865), Horrocks, White, Lane (1884).

(*d*) The order of branches is: Left common carotid, right common carotid, left subclavian, right subclavian. This is a case of low origin of the right subclavian with transposition of the carotids; only reported example is by Rau (1890).

(*e*) The order of branches is: Innominate, left carotid, left vertebral, left subclavian, see fig. 45. I have encountered three cases in my own dissecting rooms; in two of them the vertebral entered the fifth transverse foramen and in the other the fourth foramen. As far as the vertebral is concerned this group is similar to III, *C*, 1.

The following cases have been collected:

Cassebohm (Böhmer 1741), Henkel (1747), Huber (1777), Tiedemann (1822), Quain (1844), Dubrueil (1847), Barkow (1869), Carver (1869), Bradley (1871), Pye-Smith, Howse, Davies, Colley (1871), Struthers (1875), Müller (Harris 1877), Shepherd (1877), Gruber (1878), Anderson (1879), Lees (1880), Shepherd (1880), Park (1883), White, Lane, Price (1886), Hochstetter (1890) in a dog, Shepherd (1890), Thomson (1891) 5 cases, Abbott (1892), Struthers (1893) 3 cases, Freyberger (1898), Azuta (1905), Kubo & Matsui (1906), Pellegrini (1906), Waldeyer (1906), Kubo (1908), Elze (Kemmetmüller '11), Kemmetmüller (1911) 7 cases, Stein (1911), Adachi (1914) 9 cases.

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(*f*) The order of branches is: Innominate, left carotid, left subclavian, left vertebral; see fig. 46.

This condition is much less frequent than the preceding; cases have been reported by Meckel (1816), Tiedemann (1822), Szawlowsky (1906) and Adachi (1914) 2 cases.

(*g*) The order of branches is: Innominate, made up of the right common carotid and the right vertebral, the left common carotid, the left subclavian and the right subclavian. These cases have been previously reported under II, *D*, 2, and need not be repeated here.

(*h*) The order of branches is: Innominate made up of the right common carotid, the right vertebral and the left common carotid, the left vertebral, the left subclavian and the right subclavian. Cases have been reported by Brodie (1889) and Abbott (1892).

(*i*) The order of branches is: Right subclavian, a common stem for the carotids, left vertebral, left subclavian. A case has been reported by Hall (1870).

(*k*) The order of branches is: Innominate, made up of the right common carotid and the right internal mammary, left common carotid, left subclavian, right subclavian. This condition was observed by Ludwig (1764).

(*l*) The order of branches is: Innominate, left carotid, left subclavian, right vertebral. For cases illustrating this condition see section II, *D*, 3.

(*m*) The order of branches is: Innominate, left internal carotid, left external carotid, left subclavian. The group of cases listed under II, *D*, 7 are examples of this condition.

(*n*) In right aortic arch the order of branches is: Left carotid, right carotid, right subclavian, left subclavian. This arrangement has already been discussed in section II, *C*, 2, and a list of reported cases given.

(*o*) The order of branches is: Right carotid, left carotid, left subclavian, right subclavian. This arrangement is the counterpart of the preceding and represents the simplest condition in the cases of low origin of the right subclavian.

Since the classification under II, *D*, 1 is from a different standpoint, the lists of cases, while including this condition, do not in-

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dicate which are cases of four branches from the arch arranged in this order; the following list is given to satisfy such grouping.

Cassebohm (Böhmer 1741), Hoffmann (1751), Mieg (1753), Löseke (1754), Pohl (1773), Bayford (1789), Cruickshank (1789), Hulme (1789), Brewer (1791), Valentin (1791), Sandifort (1793), Monro (1797), Isenflamm (1800), Meckel (1805), Autenreith & Pfleiderer (1806) 2 cases, Zagorsky (1810), Herold (1812), Isenflamm & Fleischmann (1815), Meckel (1816) 3 cases, Otto (1816), Kirby (1818), Colles (1820) 4 cases, Stedman (1823), Hart (1826), Cerutti (1827), Mayer (1827), Weber (1829), Hopkinson (1830), Otto (1830) 3 cases, Cruveilhier (1831), Cruveilhier & Lenoir (1832), Fleischmann (1835), Harrison (1839) 2 cases, Liston (1839), Todd (1839), Gorgone (1841), Quain (1844), Reid (1846) 2 cases, Arnold (1847), Blandin (1842), Demarquay (1848) 2 cases, Stachelroth (1850), Frandsen (1854), Oehl (1859) 2 cases, Peacock (1860) 4 cases, Turner (1862) 4 cases, Barkow (1866), Barwell (1867), Barkow (1869) 6 cases, Peacock (1870), Eppinger (1871), Mears (1871), Pye-Smith, Howse, etc. (1871), Düben (1876), Krause (1876), Shepherd (1877), Zenker (1878) 5 cases, Flesch (1879), Walsham (1880), Wiltshire (1881), Brown (1882), Giacomini (1882) 2 cases, Ozenne (1883), Horracks, White, Lane (1884), Beisso & Giuria (1886), Struthers (1888), Deaver (1889), Mann (1889), Dunn, Washburn & Targatt (1890), Ledouble (1890), Thompson (1890), Bothezat & Chatinière (1891), Thomson (1891) 2 cases, Faure (1895), Testut (1896) 2 cases, Miura (1897), Anile (1898), Holzapfel (1899), Rolly (1899), Hamann (1900), Ledouble (1901) 3 cases, Bouchet (1903), Gérard (1906), Pearce-Gould (1909), Geddes (1910), Hasebe (1912), Cobey (1914), Warren Museum 2 cases.

(*p*) The order of branches is: Innominate, internal mammary (dext.), left carotid, left subclavian. Cases reported by Loder (1781) and Meckel (1816).

(*q*) The order of branches is: Innominate, right inferior thyroid, left carotid, left subclavian. Two cases are reported by Meckel (1816).

(*r*) This is similar to the preceding except that the inferior thyroid goes to the left side and is situated between the left carotid and left subclavian. Cases are reported by Nicolai (1725), Hyrtl (1841), Gottschau (1885) 2 cases, Taylor & Grell (1902).

(*s*) The order of branches is: Innominate, left carotid, left superior intercostal, left subclavian. Macalester (1886) reported two examples of this condition.

(*t*) The order of branches is: Innominate, left thymic, left

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carotid, left subclavian. Cases reported by Huber (1777) and Hyrtl (1841).

2. *Number of Branches Five.*—The number of branches from the arch five and classified according to their arrangement as follows:

(*a*) The order of branches is: Innominate, right vertebral, left carotid, left vertebral, left subclavian; see fig. 48. Cases are reported by Penada (1801), Fiorati (1805), Meckel (1805), Huber (Tiedemann, 1822).

(*b*) The order of branches is: Innominate, composed of the right carotid and vertebral, left carotid, left vertebral, left subclavian, right subclavian. These cases are included in section II, *D,* 1, and are as follows:

Tiedemann (1846) 2 cases, Bankart, Pye-Smith, Phillips (1869), Barkow (1869), Giacomini (1882), Brenner (1883), Shepherd (1890).

(*c*) The order of branches is: Right subclavian, right carotid, left carotid, left vertebral, left subclavian. This condition has been reported by Petsche (1736) and Loder (1781).

(*d*) The order of branches is: Right carotid, left carotid, left vertebral, left subclavian, right subclavian. These cases have been reported as a part of the list of section II, *D,* 1, classifying the low origin of the right subclavian.

They are as follows:

Koberwein (1810), Meckel (1820), Godman (1824), Hesselbach (1824), Quain (1844) 2 cases, Bankart, Pye-Smith, Phillips (1869), Pye-Smith, Howse, Davies, Colley (1871), McArdle (1885).

(*e*) The order of branches is: Right carotid, left carotid, left subclavian, left vertebral, right subclavian. This is similar to the last group, except that the left vertebral follows the left subclavian on the arch; a case has been reported by Wagner (1828).

(*f*) The order of branches is: Innominate, right internal mammary, left carotid, left vertebral, left subclavian. Cases have been reported by Casselbohm (Böhmer, 1741) and Meckel (1816).

(*g*) In a right arch the order of branches is: Left carotid, right carotid, right vertebral, right subclavian, left subclavian. Cases

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are reported by Otto (1824), Hermann (1830), Barkow (1869), Watson (1877) and Abbott (1892).

(*h*) In a right arch the order of branches is: Innominate, composed of the left carotid and left vertebral, right carotid, right vertebral, right subclavian, left subclavian. A case has been reported by Brenner (1883).

3. *Number of Branches Six.*—The number of branches from the arch six; classified according to arrangement as follows:

(*a*) The order of branches is: Right subclavian, right vertebral, right carotid, left carotid, left vertebral, left subclavian; see fig. 49. Cases are reported by Müller (Meckel, 1817), Tiedemann (1822) and Harrison (Quain, 1844).

(*b*) The order of branches is: Innominate, left carotid, two left vertebrals, left inferior thyroid, left subclavian. A case is reported by Kemmetmüller (1911); in this case a thyreoidea ima came from the innominate.

§ VIII

E. Irregularities of the Individual Arteries Grouped Together

Irregularities of the several arteries are grouped together in this section under the headings of the arteries for the benefit of those who wish to consult anomalies from this standpoint.

1. *Thyreoidea Ima.*—The thyreoidea ima was first described by Nicolai (1725) and, as Neubauer (1722) pointed out, must not be confused with the inferior thyroids. Its frequency has been placed as high as 10 percent (Morris's *Human Anatomy,* Jackson), but this would appear to be too high; Adachi (1914) encountered only one case in 271 subjects. In my own experience two cases, one from the arch between the left carotid and left subclavian and one from the innominate, have been found.

The artery when present shows wide variation in its origin; Gruber (1872) analyzed 80 reported cases as follows: from the arch 12 cases, 9 between innominate and left carotid, 2 between right subclavian and right carotid, 1 between the left carotid and subclavian; 39 from the innominate; 16 from the carotid; 6 from the internal mammary; 3 from the right subclavian; 1 from the

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right inferior thyroid; 1 from the transverse scapular. It may accompany other irregularities as in the cases of Patterson (1884) and Taylor & Grell (1902). Keith (1895) has observed the artery in the chimpanzee.

The following references are offered; and for illustration see fig. 41.

From the innominate: Neubauer (1785), Shepherd (1877) (1880), Beaumanoir (1882), Paterson (1884), Shepherd (1889), Freyberger (1898), Taylor & Grell (1902).

From the arch: Nicolai (1725), Neubauer (1772), Loder (1781), Neubauer (1785), Portal (1804), Thiloco (1804), Meckel (1816), Tiedemann (1822), Breschet (1826), Velpeau (1826), Otto (1830), Blandin (1834), Harrison (1839), Quain (1844), Gruber (1845 and 72), Hyrtl (1859), Kemmetmüller (1911), Adachi (1914).

2. *Thymic Arteries.*—These may arise from the ascending aorta, section III, *A*, 2, from the arch, section III, *D*, 1, *t*, or from the innominate, Taylor & Grell (1902). This is an infrequent anomaly and of little morphological interest.

3. *Internal Mammary.*—This may arise from the ascending aorta, section III, *A*, 2, from the aortic arch, sections III, *D*, 1, *p*, and III, *D*, 2, *f*, and from the innominate, section III, *D*, 1, *k*.

4. *Vertebrals.*—These show a wide range of variation, which has been exhaustively studied by Kemmetmüller (1911); he has shown that the foramen which the artery enters indicates which segmental is represented in its origin and this assists materially in classifying some of the anomalies. His general classification is excellent, but too exhaustive to be followed in this brief review.

The right vertebral may arise from the aortic arch between the innominate and the left carotid, section III, *D*, 2, *a;* from the arch between the right subclavian and right carotid, section III, *D*, 3, *a;* from the arch between the right carotid and right subclavian in cases of right aortic arch, section III, *D*, 2, *g* and *h;* from the innominate in cases of low origin of the right subclavian, sections II, *D*, 1, and II, *D*, 2; as the last branch from the arch, section II, *D*, 3.

The left vertebral may arise, from the aortic arch just preceding the left subclavian, sections III, *C*, 1; III, *D*, 1, *e*, *h*, *i;*

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III, *D*, 2, *a*, *b*, *c*, *d*, *e*, *f*; III, *D*, 3, *a b*; from the arch as the last branch, sections III, *C*, 2, III, *D*, 1, *f*; from the innominate, section III, *D*, 2, *h*.

§ IX

IV. THE VARIATIONS IN THE DEVELOPMENT OF THE THORACIC DUCT

Anomalies of the thoracic duct are considered in this paper because they frequently appear in conjunction with the cases of low origin of the right subclavian artery. Calori (1890) has studied this condition and concludes that there is no relation between the two anomalies; with this conclusion I am agreed because an analysis of the cases of low subclavian shows that only a part of them also have an anomalous thoracic duct and that the type of irregularity is not constant and may be found in cases with no other developmental defect.

The irregularities in the position and number of connections of the left duct with the venous system are matters of common knowledge and need not be reviewed; we will confine this review to the cases in which all or a part of the system opens into the veins on the right side.

We are quite sure that the thoracic duct begins as a paired structure in relation to the two dorsal aortae and that the single duct is the result of a fusion of the two ducts in somewhat the same manner as the single dorsal aorta is formed. More observations are needed at the cephalic end to determine whether the right duct normally develops as the right aorta does and disappears by a similar atrophy. The embryonal history may be illustrated if we may consider these cases of arrested development, or rather development in the type of embryonal stages. Sömmering (1841) saw a case in which two ducts ran from the receptaculum chili to the venous angles in the neck, one duct opening on the right and one on the left. In Duval's (ref. Todd '39) case the duct was double in the abdomen. Butler (1903) saw a case in which the duct was double in the thorax, then single for about an inch opposite the third thoracic vertebra, then continued as two separate ducts, one opening on the left and the other on the right. Numerous examples have been reported in which both

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ducts persist above, their union occurring opposite the third or fourth vertebra, see my case, page 34, illustration fig. 25, and examples below.

There is a specimen in the Warren Museum in which the duct passes up on the right of the aorta to the third dorsal vertebra where it crosses to the left, divides into two trunks and these continue as separate channels to their termination, one in the venous angle and the other in the jugular behind; both are left ducts. All the arteries are normal.

Persistence of both the right and left duct is seen in conjunction with double aortic arch, Watson (1877), and in low origin of the right subclavian, my case, page 34; it may be noted in the latter that the left duct is smaller than the right, suggesting that this is an intermediate stage in the cases of persistent right duct only.

Persistence of the right duct and obliteration of the left has been observed in cases of right aortic arch, of the type presenting a left innominate, Thomson (1863), Reid (1914), case II. It has also been observed in right aortic arch of the type in which the left subclavian is the last branch, Combes & Christopherson (1884). It may be found in cases of low right subclavian, see below, although in these double duct is almost as frequently encountered.

From the above it will be seen how difficult it is to discover a relationship between arterial variations and thoracic duct variations. It would seem that the factors which operate to produce a low right subclavian artery also tend to establish the right duct as a functioning structure. If as pointed out, page 33, the low right subclavian is related to the cases of right aortic arch of the type having a low left subclavian we would expect, reasoning as above, that the left duct would be the one developed and this is the case. This result in the case of the right arch with low left subclavian, however, does not prove that the disturbing developmental factors have influenced the duct for we are here dealing with a duct that is normal.

I would conclude from a consideration of all of the cases of anomalous thoracic duct, taken in conjunction with arterial varia-

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tions, that duct irregularities are independent of arterial variations except in so far as developmental disturbances affecting the arteries may be so far reaching as also to affect the thoracic duct.

The following is a list of cases illustrating thoracic duct anomalies:

Duct opening on both sides in cases of low right subclavian: Meckel (1772), Cruickshank (1789), Fleischmann (1815), Brown (1882), Hasebe (1912).

Duct opening on right in cases of low right subclavian: Walter (1785), Sandifort (1793), Hart (1826), Todd (1839), Stachelroth (1850), Brenner (1883) 2 cases, McArdle (1885), Calori (1890), Gladstone & Wakeley (1915).

Right duct persists with or without other anomalies: Hommel (1737), Haller (1766), Mascagni (1787), Cruickshank (1789), Fleischmann (1815), Meckel (1816), Otto (1824–30), Todd (1839), Sömmering (1841), Teichmann (1861), Thomson (1863), Watson (1872), Combes & Christopherson (1884), Davis (1886), Szalowsky (1888), Reid (1914).

§ X. GENERAL SUMMARY

From the preceding study certain impressions have been gained, which I will present as conclusions; fully appreciating, however, that in many cases much needed data was not possible to obtain and that the developmental problems are approached from only one standpoint.

There is no satisfactory evidence of a fifth aortic arch in any of the anomalies studied.

Factors disturbing the orderly development of the different portions of the vascular system may act independently of and without disturbing the normal growth processes. When the general circulatory system is seriously interfered with on account of these factors, compensation occurs either through arrest of normal atrophic processes or by enlargement of normal channels.

The factor or factors producing situs viscerum transversus seem to be operative on the aortic arch but not on the pulmonic arch.

The study of transposition shows that four separate growth

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centers, viz., truncus arteriosus, bulbis cordis, ventricular limb and arterial limb, must be considered and that any one or more may show irregular development while the remainder develop normally.

It would seem that the tendency to develop is stronger in the left dorsal aorta than in the left fourth arch if we may judge from the more frequent type of right aortic arch.

Factors disturbing vascular development apparently act at a very early stage and on a very restricted area. In interpreting anomalies we should attempt to fix the time and position of disturbance if we are to throw light on the factors themselves.

There is insufficient embryological data to explain many of the anomalous arrangements of the branches from the aortic arch and it would seem that these problems might be solved by a study of the lower mammals, in which these anomalies are type forms.

There is no way of determining accurately the percentage frequency of the various anomalies in relation to the normal; the list below shows the percentage in relation to the total number of abnormalities noted. In securing these figures I have divided the irregularities into two groups one, sections I and II, relating more

Group 1

	Percent.
Irregular development of the aortico-pulmonary septum	7.3
Atresia of the pulmonary artery	6.8
Transposition of aorta and pulmonary artery	17.7
Patent ductus arteriosus	20
Double aortic arch	2.2
Right aortic arch	9
Low origin of right subclavian artery	31
Absence of the third arch	2

Group 2

One branch from aortic arch	3
Bi-innominate trunks	3
Bi-carotid trunk	25
Left carotid from the innominate	20
No innominate stem. (Low origin of subclavian not included)	8
Left vertebral from aortic arch	30
Right vertebral from aortic arch	4.7
Unusual branches from the aortic arch	2.5

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particularly to arrest of development; and the other, section III, relating to fusion or separation of branches of the aortic arch. Since all of the evidence goes to show that the several disturbing developmental factors may operate independently of each other, these figures have no statistical value except to show the relative frequency of the cases included in this study.

The anomalies of the thoracic duct can all be explained from the embryological development. The duct shows less tendency to irregular development than the arteries of the same region, and the duct irregularities are independent of arterial variations except in so far as developmental disturbances affecting the arteries may be so far reaching as also to affect the thoracic duct.

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ABBREVIATIONS USED IN THE FIGURES

A. Aorta.
A D. Aorta descendens.
C. Arteria carotis.
C D. Arteria carotis communis dextra.
C S. Arteria carotis communis sinistra.
D. Ductus arteriosus (Botalli).
E C. Arteria carotis externa.
I C. Arteria carotis interna.
O. Oesophagus.
P. Arteria pulmonalis.
S D. Arteria subclavia dextra.
S S. Arteria subclavia sinistra.
T. Trachea.
T D. Ductus thoracicus.
V D. Arteria vertebralis dextra.
V S. Arteria vertebralis sinistra.

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PLATE I.

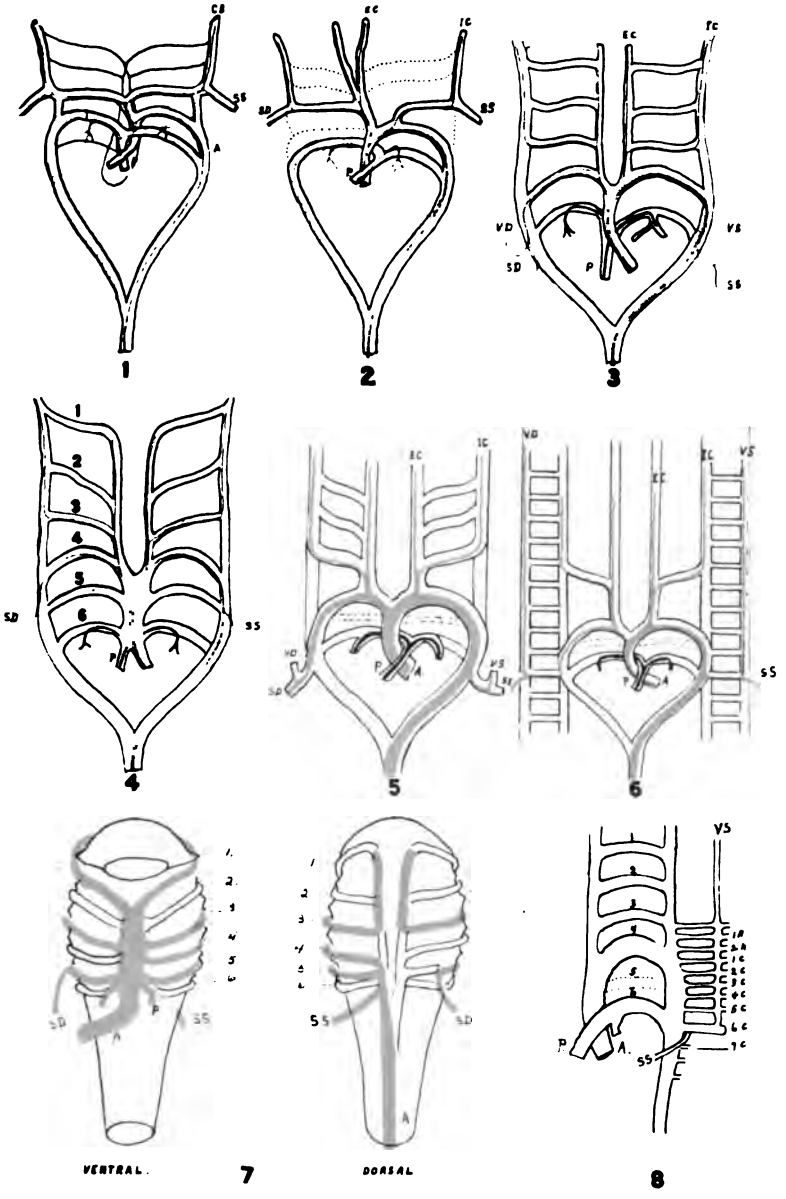

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PLATE II.

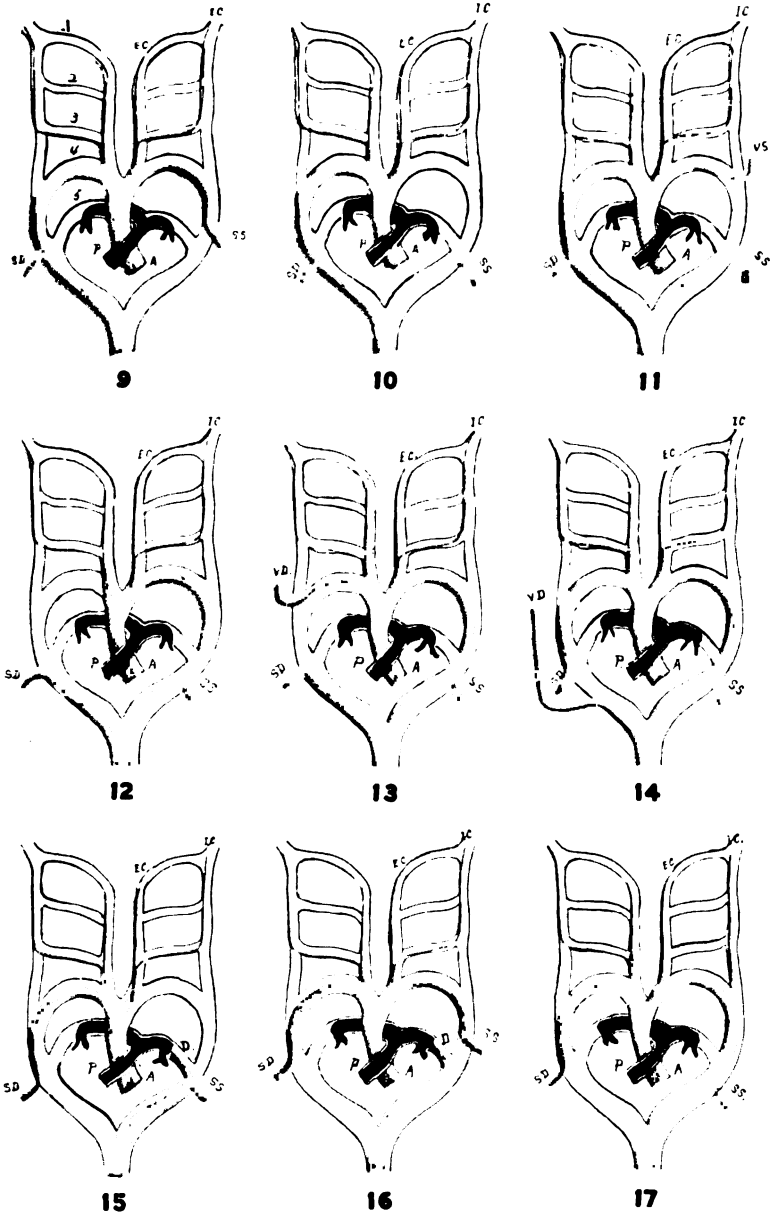

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PLATE III.

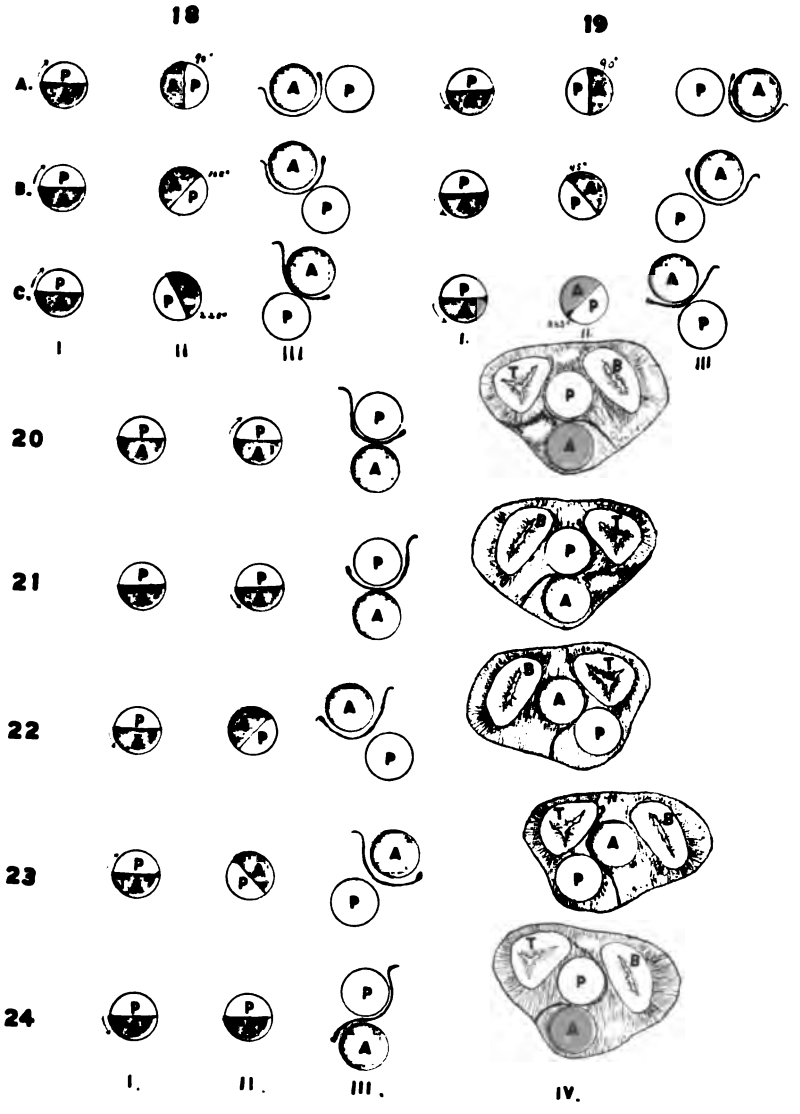

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PLATE IV.

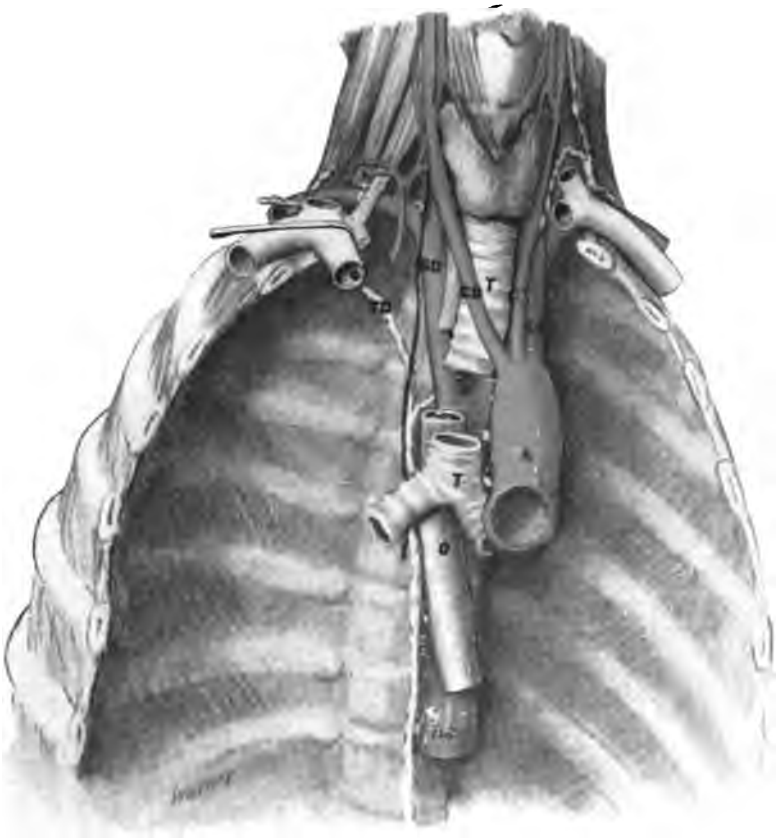

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PLATE V.

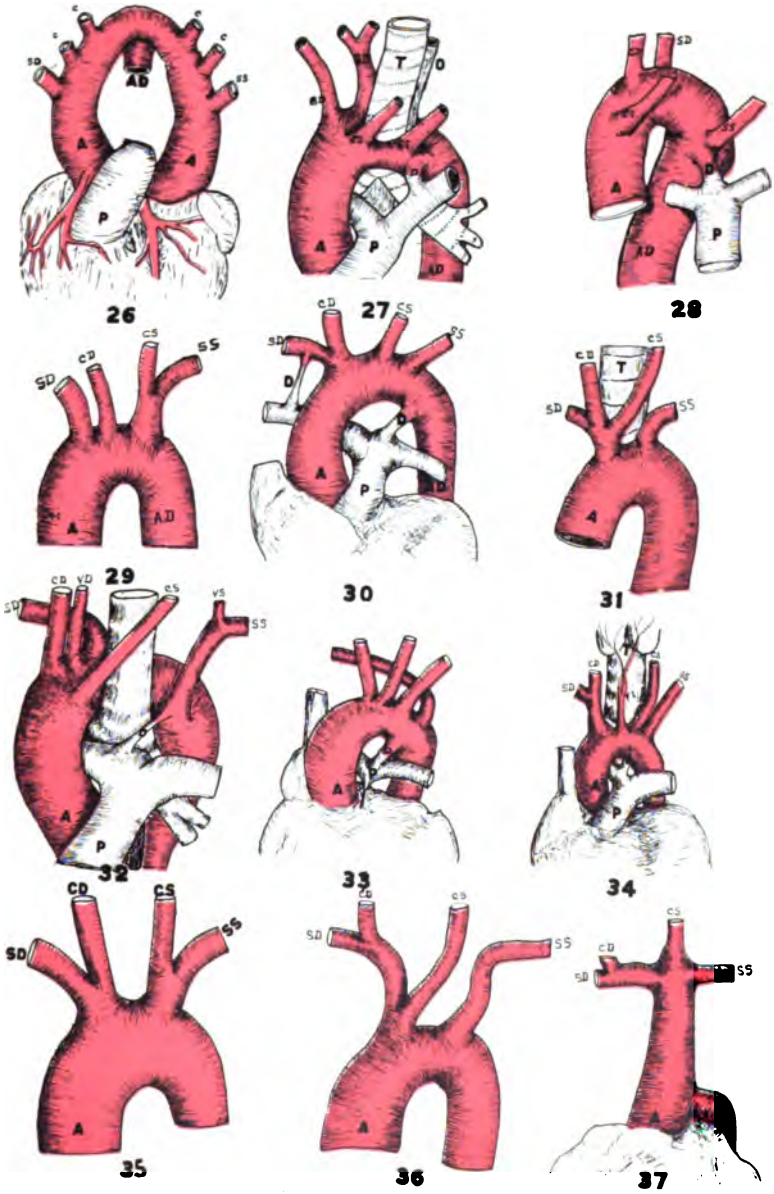

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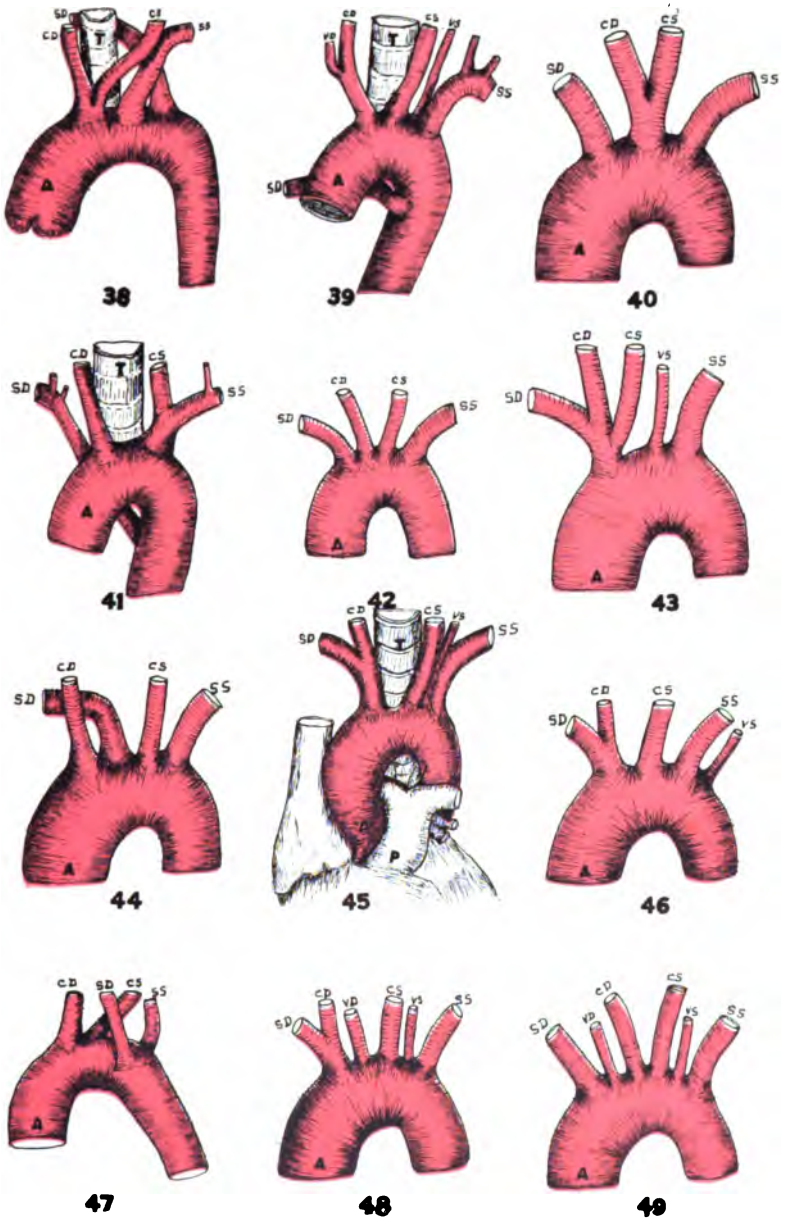
PLATE VI.



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Explanation of Figures

Fig. 1. This figure represents the fig. 3, Plate II, used by v. Baer to illustrate what he, at that time, thought was the type of development of the aortic arches in mammals. It was copied by Thomson (1831) as fig. 39, although he did not give v. Baer credit for the mammalian figure but for the right arch figure for birds, his fig. 30, and claimed priority for the presentation of the mammalian type.

Fig. 2. This figure represents the fig. 14, Plate IV, which v. Baer (1837) used to illustrate his embryology. He offered this figure in place of the one above to correct certain misconceptions of the fate of the aortic arches in mammals. He was of the opinion that the primitive third arch on each side forms the arterial stem which divides into the internal carotid subclavian and vertebral arteries, and that the external carotids arise from the low persisting portion of the two first arches of one half side of the head.

Fig. 3. This figure represents fig. 10, Plate VI, offered by Rathke (1857) to correct the errors in interpretation which he considered v. Baer had made for mammals. The development of the carotids and subclavians in the main is correct and the relation of the pulmonary arteries to the fifth arch is for the first time presented. This figure has frequently been presented as if it represented the first attempt at interpreting the arches, when in fact it is merely one step in the progress of our understanding of these structures.

Fig. 4. This figure represents fig. 1, Plate I, offered by Boas (1888) to illustrate the development of the aortic arches in mammals and especially to introduce an additional arch between the fourth and pulmonary arches which he believed had been overlooked by previous observers.

Fig. 5. This figure represents our present understanding of the development of the aortic arches in mammals and is used in this study as the basis for modifications explaining the various anomalies encountered in this work.

Fig. 6. This figure is adapted from Kemmetmüller (1911) to illustrate the development of the vertebral arteries and the possible variations they may assume due to anomalous development.

Fig. 7. This figure is adapted from Banchi (1907), his fig. 7, used to illustrate the method of development of the low subclavian, taking a pretracheal course. This method of solid reproduction of the arches was used by His, and Banchi urges that it is much easier by this type of figure to present the actual condition of the arches than by the plane figure, as above.

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FIG. 8. This figure is adapted from Hochstetter's (1906) fig. 118, showing the development of the vertebral arteries; it differs in no essential detail from fig. 6, above, which was suggested by one of his earlier figures.

FIG. 9. A schematic representation of the development in cases of right aortic arch, in which there is present a left innominate; see Sect. II, *C*, 1.

FIG. 10. A schematic representation of the development in cases of right aortic arch in which the left subclavian artery is the last branch of the arch; see Sect. II, *C*, 2.

FIG. 11. This condition is similar to fig. 10, except that the left vertebral artery springs apparently from the left common carotid instead of the left subclavian; see Sect. II, *C*, 3. This figure was first used by Brenner (1883) as fig. 5, Plate 17.

FIG. 12. A schematic representation of the development in cases in which the right subclavian artery is the last branch from the arch. The figure was first used by Wood (1859) and has been variously modified to illustrate pre-tracheal and pre-œsophageal cases; for discussion see Sect. II, *D*, 1, and for illustration figs. 7, 25, 39 and 41.

FIG. 13. This is similar to fig. 12 except that the right vertebral arises from the right common carotid instead of the right subclavian artery; see Sect. II, *D*, 2.

FIG. 14. A schematic representation of the development in cases in which the right vertebral artery arises from the aortic arch as the last branch; see Sect. II, *D*, 3.

FIG. 15. A schematic representation of the development in cases in which the pulmonary artery through the ductus arteriosus gives origin to the dorsal aorta and the left subclavian artery; see Sect. II, *D*, 4.

FIG. 16. Like fig. 15 except that the left subclavian artery seems to arise from the ascending aorta by a common trunk with the left common carotid artery; see Sect. II, *D*, 5.

FIG. 17. A schematic representation of the development in cases in which the common carotid is absent and the internal and external carotids arise directly from the aortic arch; see Sect. II, *D*, 6 and 7.

FIG. 18. A diagram showing varying degrees of torsion of the great vessels with corresponding arrangement of the bulbar and ventricular septa: *A*, torsion of 90 degrees; *B*, normal or torsion of 135 degrees; *C*, torsion greater than normal. In both *A* and *C* we must consider the condition normal except for the actual position of the vessels and the adaptation imposed on the ventricular loop.

All of the figures on this plate are adapted from the figures of Rokitansky (1875) and Robertson (1913*a*); see Sect. I, *C*.

FIG. 19. Diagrams representing a mirror picture of fig. 18 and illustrating the possible positions of the vessels and septa in cases of situs viscerum transversus.

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FIG. 20. Diagrams representing the positions of the bulbar and ventricular septa in simple transposition of the aorta and pulmonary arteries: I shows the position of the distal part of the aortico-pulmonary septum; II shows the position of the proximal aortico-pulmonary septum; III shows the possible arrangement of the great vessels in relation to the interventricular septum; IV shows the possible relation of the great vessels in relation to the ventricular chambers (heart normal and aorta opens from a tricuspid ventricle).

FIG. 21. Diagram representing the possible arrangement of vessels and heart in transposition of the great vessels accompanied by dextro-cardia.

FIG. 22. Diagram showing the possible arrangement of the ventricular chambers and the great vessels in cases in which the bulbus rotates to the left and the ventricular loop to the right.

FIG. 23. Diagram showing the possible arrangement of the ventricular chambers and the great vessels in cases of dextro-cardia, in which the vessels have developed normally.

FIG. 24. Diagram representing the possible arrangement of the ventricular chambers and the great vessels in the cases of transposition in which the aorta is in front of the pulmonary artery but opens from a bicuspid ventricle.

FIG. 25. This drawing was made from a dissection in our laboratory of a case in which the right subclavian artery arose from the beginning of the dorsal aorta and passed behind the œsophagus. The thoracic duct divided near the origin of the subclavian and opened on each side into the venous angle; see page —.

FIG. 26. This figure, representing a case of true double aortic arch, was taken from Tiedemann (1822), fig. 7, Plate IV, representing a case described by Malacarne (1788), Pt. 2, p. 119; it was copied by Quain (1844) as fig. 8, Plate V, and by Krause (1876) as fig. 108*a*.

FIG. 27. This figure, representing a case in which the arch alone is double, was taken from Tiedemann (1822), fig. 6, Plate IV, representing a case described by Hommel (1737). It is referred to in Haller Elem. Physiol., tom. 2, p. 162, and copied by Quain (1844) as fig. 7, Plate V, and by Krause (1876) as fig. 108*b*.

FIG. 28. This figure, representing a case of right aortic arch with the left subclavian artery as the last branch and the ductus arteriosus patent, was taken from Quain (1844), fig. 2, Plate VII.

FIG. 29. This figure, representing a case of right aortic arch with a left innominate trunk, was taken from Tiedemann (1822), fig. 9, Plate IV.

FIG. 30. This figure, representing a case of persistence of both the right and left ductus arteriosus, was taken from Breschet (1826), fig. 9, Plate I.

FIG. 31. This figure, representing the more or less common anomaly of left carotid artery springing from the innominate trunk, was copied from Tiedemann (1822), fig. 5, Plate II.

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FIG. 32. This figure, representing a case of right aortic arch, with the left subclavian artery as the last branch and the right vertebral springing from the arch, was taken from Abbott (1892), fig. 1.

FIG. 33. This figure, representing a case of atresia of the pulmonary artery, was taken from Keith (1909), fig. 4; the pulmonary artery leaves the heart as a fibrous cord but rapidly enlarges to about normal, the ductus arteriosus is patent.

FIG. 34. This figure, representing a case of thyreoidea ima springing from the arch, was taken from Neubauer (1786), fig. 2, Plate VII.

FIG. 35. This figure, representing a case of bi-innominate trunks, was taken from Tiedemann (1822), fig. 4, Plate II, and copied by Quain (1844), fig. 9, Plate VI.

FIG. 36. This figure was drawn from a specimen of left common carotid springing from the innominate, which is in the Warren Museum.

Fig. 37. This figure, representing a single branch from the aortic arch, was taken from Tiedemann (1822), fig. 3, Plate II, illustrating the case of Klinz (1793), p. 273. It was copied by Quain (1844), fig. 6, Plate V.

FIG. 38. This figure was drawn from a specimen of low origin of the right subclavian with both carotids springing from a common stem, which is in the Warren Museum.

FIG. 39. This figure, taken from Krause (1876), fig. 115 (Macartney), Tiedemann, 1846, fig. 6, Plate XXXIX, represents a case of low origin of the right subclavian artery with the right vertebral springing from the right common carotid and the left vertebral from the aortic arch.

FIG. 40. This figure, representing a case of common trunk for the carotids, was taken from Tiedemann (1822), fig. 2, Plate III, copied by Quain (1844) as fig. 4, Plate VII.

FIG. 41. This figure, representing a case of low right subclavian artery, with a common stem for the left carotid and subclavian, was taken from Tiedemann (1822), fig. 6, Plate II; copied by Quain (1844) as fig. 8, Plate VII.

FIG. 42. This figure, representing a case in which all four branches spring separately from the arch, was taken from Tiedemann (1822), fig. 3, Plate III; copied by Quain (1844) as fig. 10, Plate VI.

FIG. 43. This figure, representing a case of the left common carotid arising from the innominate trunk and the left vertebral from the arch, was taken from Tiedemann (1822), fig. 7, Plate II.

FIG. 44. This figure, representing a case of the right subclavian arising as the second branch from the arch, was taken from Tiedemann (1822), fig. 4, Plate III; copied by Quain (1844) as fig. 11, Plate VI. The original was by Huber (1777), vol. 8, p. 75 and fig. 3.

FIG. 45. This figure is adapted from a case of left vertebral arising from the aortic arch which was found in our dissecting rooms.

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FIG. 46. This figure, representing a case in which the left vertebral is the last branch from the arch, was taken from Tiedemann (1822), fig. 10, Plate III; copied by Quain as fig. 10, Plate VII.

FIG. 47. This figure, representing the right subclavian as the third branch from the arch, was reported by Walter (1785), p. 62, fig. 5, Plate III; it was copied by both Tiedemann and Quain.

FIG. 48. This figure, representing five branches from the arch, was reported by Penada (1801), p. 44, and figured by Tiedemann (1822) as fig. 4, Plate IV.

FIG. 49. This figure, representing six branches from the arch, was taken from Tiedemann (1822), fig. 5, Plate IV; copied by Quain (1844) as fig. 15, Plate VII.

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